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ABSTRACT

Presented are the proceedings, papers, and analysis of papers for the twentieth anniversary Conference of the Science and Mathematics Teaching Center at Michigan State University. The Conference was held to recognize past contributions of the Center and to propose and examine future directions in Science and Mathematics Education. Specific objectives included: (1) need assessment; (2) present positions on issues affecting science and mathematics education; (3) generate historical papers relating to the Science and Mathematics Teaching Center; (4) review accomplishments of the Center; and (5) to recognize contributions to the Center. (SH)

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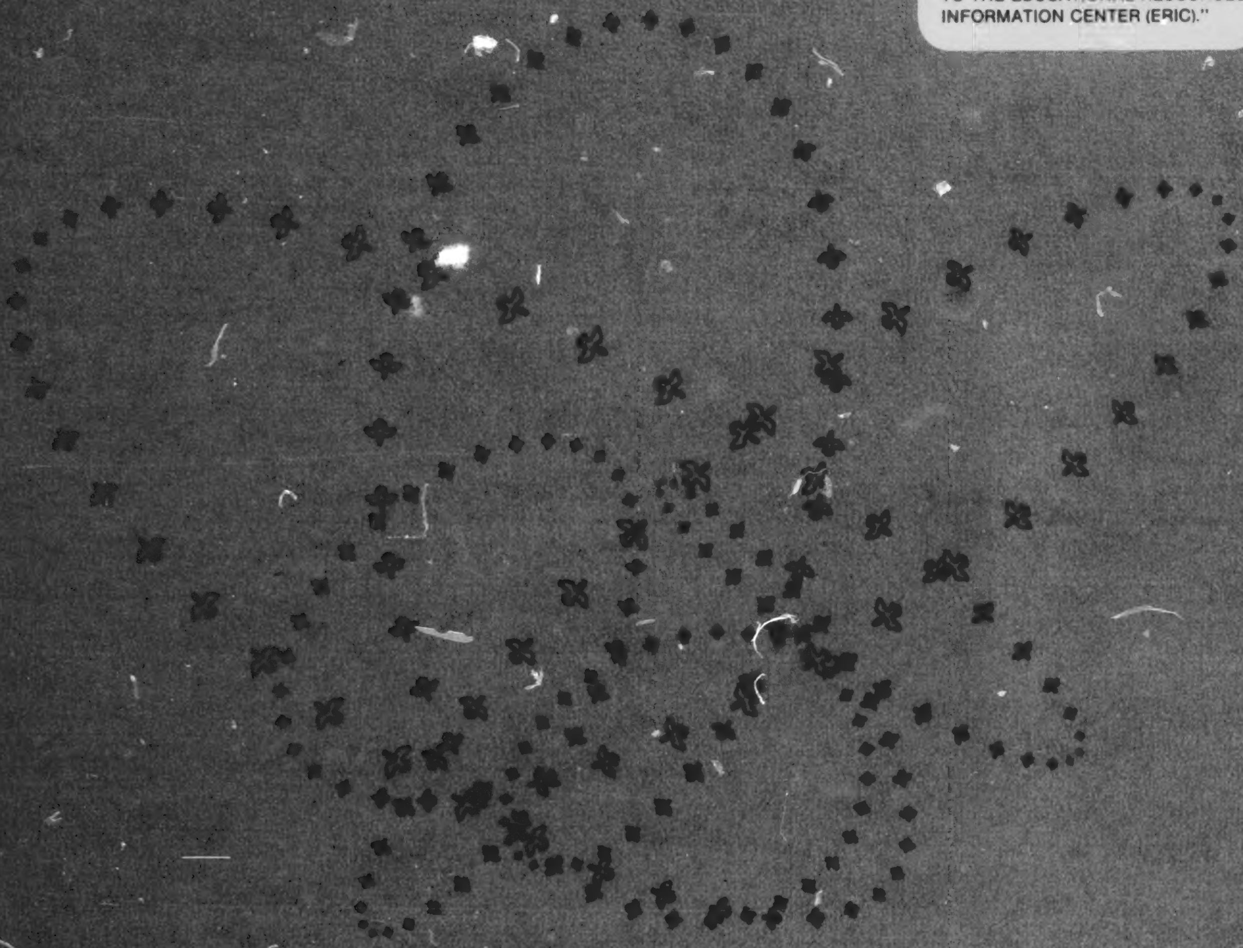

PROCEEDINGS OF THE CONFERENCE MARKING THE TWENTIETH
ANNIVERSARY OF THE SCIENCE AND MATHEMATICS TEACHING
CENTER

May 17, 1977
McDonel Hall
Michigan State University
East Lansing, Michigan

SE 024 256

PROCEEDINGS OF THE CONFERENCE MARKING THE TWENTIETH ANNIVERSARY OF THE SCIENCE AND MATHEMATICS TEACHING CENTER

Compiled and edited by
Richard Brandenburg

and

James Joseph Gallagher

May 17, 1977

McDonel Hall

Michigan State University

East Lansing, Michigan

Preface

1977 marked the Twentieth Anniversary of the establishment of the Science and Mathematics Teaching Center at Michigan State University. On May 17, 1977 a Conference was held at McDonel Hall on the MSU campus to commemorate this anniversary. The purpose of the Conference was to recognize past contributions to the Center and to propose and examine future directions in Science and Mathematics Education. Specifically, the objectives of the Conference were:

1. to assess needs of the science education and mathematics education communities for the decade ahead;
2. to solicit reactions from University and school personnel to proposed thrusts of the Science and Mathematics Teaching Center;
3. to present positions on selected contemporary and future issues affecting science and mathematics education;
4. to generate a Twentieth Anniversary Publication containing papers on the history, accomplishments, and future plans of the Science and Mathematics Teaching Center and selected position papers on important issues in science and mathematics education;
5. to review the accomplishments of the Center; and
6. to recognize the contributions of Michigan State University personnel, school supervisors, teachers, administrators, and others who have worked with the Center staff over the years in a wide range of efforts.

Advance copies of nine position papers, drafted by the SMTC staff and associates, were mailed to selected Conference participants in order to assure a thorough review and response. During part of the May 17th meeting groups of Conference participants met in nine simultaneous analysis workshops to discuss these papers and related issues. Short reports on these workshops were prepared by a "Rapporteur" from each group.

This document consists of the nine papers, revised to reflect the insights and analysis gained during the Conference, the Rapporteur's reports and the opening and closing addresses and comments by Dr. Lee Shulman, Dr. Robert Silber, and Dr. James Joseph Gallagher.

This conference was made possible through special grants from the College of Education and the College of Natural Science, Michigan State University, and from the Consumers Power Company. Special thanks are extended to Keith Goldhammer, Dean of the College of Education, Richard Byerrum, Dean of the College of Natural Science, and to our many friends and colleagues for their contributions and support in this effort.

The Front Cover: "Bird Curves" a computer graphic by William Kolomyjec. This work was part of a larger collection of "Science Connected" Art exhibited at the SMTC Twentieth Anniversary Conference.

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INTRODUCTION TO THE TWENTIETH ANNIVERSARY CONFERENCE

James Joseph Gallagher
Director, Science and Mathematics
Teaching Center
Michigan State University

INTRODUCTION TO THE TWENTIETH ANNIVERSARY CONFERENCE

Dr. James Joseph Gallagher

I am pleased that our Conference marking the Twentieth Anniversary of the Science and Mathematics Teaching Center has resulted in an assembly of leaders in science and mathematics education. We have nearly 150 people here today. Nearly half of the participants are from the elementary and secondary schools of Michigan, while the others come from departments here at MSU and from several of our sister institutions of higher education in Michigan. We also have visitors from Pennsylvania, New York, Canada, Israel, and Australia.

One purpose of this conference is to express appreciation for your past contributions to the Science and Mathematics Teaching Center which have helped to make it an outstanding unit, respected on campus, across the state, and nationally. Neither this Conference, nor the Science and Mathematics Teaching Center could exist without your volunteer service and cooperation. My associates and I wish to thank you for your cooperation and, at the same time, we wish to ask for its continuance in the future.

Since I am relatively new at MSU, I am looking forward to the opportunity of getting to know you today and working with you in the future.

I have a few introductions to make. First of all, the three people who are helping us with the sponsorship of the Conference, Dean Byerrum of the College of Natural Science, Dean Goldhammer of the College of Education, and Dick Bradley, representing Consumers Power. I also wish introduce Dean Emeritus Fred Dutton, who was the founder and first director of the Science and Mathematics Teaching Center, and Julian Brandou, the second Director of the Center. Additionally, I would like to introduce the faculty of the Science and Mathematics Teaching Center. I'll ask them to stand so that those of you who have not met them as yet, will recognize them; Glenn Berkheimer, Jean Enochs, Marty Hetherington, Betty Karmann, Dick McLeod, Carl Naegele, and Ed Smith. Also, our office manager and bookkeeper, Tena French, is responsible for the operation and the functioning of this conference, and we thank her very much for her help and cooperation in this venture.

We also have a visiting faculty member who is with us for a short time. Many of you have met him, he is Pinchas Tamir, visiting from the University of Jerusalem. There are two measures of his competence that I think we should note. One is that Lee Shulman asked him to co-author the keynote address with him. That certainly is a distinct, positive assessment of his competence. Secondly, Pini just received the Palmer-Johnson Award for outstanding Research by the (AERA) American Educational Research Association.

I would also like to introduce the authors of the nine papers that will be the focus of the Analysis Workshops today. The author of the paper on Scientific Literacy, the focus of the first of our Analysis Workshop, is Michael Agin. Mike is here from Michigan Tech where he is Professor of Science Education. Jean Enochs from our faculty, is the author of the paper on Biology Preparation of Elementary Scienc Teachers. Keith Hamman authored the paper, "Problem Solving in Mathematics." Keith, must hold the record for distance since he is visiting from Australia. Of course, he is spending the year here and we just happened to get him to work with us on this Conference. Martin Hetherington wrote the paper

Energy Education and John Masterson authored the paper on the Experimental Teacher Training Program in Mathematics. Dick McLeod prepared the paper on Inservice Education and Carl Naegele is the author of the paper on Learning Theory. Ed Smith and Glenn Berkheimer co-authored the paper on Research in Science and Mathematics Education and Lauren Woodby, authored the paper on Hand Calculators in the Classroom.

As you can see around us, we have an art show associated with the Conference. It will be here today and then it will be on display in Abrams Planetarium for the rest of May. When we first started planning this Conference, several months ago, I had an idea that a show of science related art would be a useful adjunct to it. I spoke about this idea and one of our graduate students turned the idea into a reality. That student is Rick Brandenburg and I think that Rick needs a real speckal tribute for the effort that he went through in making the idea a reality. Rick is one of those people with unique capability. He and Tena also put together the program for today.

This presentation is supposed to be an "Overview of the Conference" and I will make it very brief, to allow our keynote speaker adequate time.

The main purpose of the Conference is, to assess the needs of science and mathematics education for the decade ahead, to solicit reactions to our proposed directions, to say thanks for help in the past, and to ask for your help in the future. The plan of the Conference is outlined in the program, and consists of (1) the keynote address, (2) the analysis workshops, (3) the luncheon program, (4) the panel discussion, and (5) the closing address.

The analysis workshops are designed to provide a mechanism for authors to obtain reactions to the specific papers. Each workshop will consist of two sessions of about one hour each. In each the author, a discussion leader, a rapporteur, a graduate student and several participants will engage in an analysis of the paper ("Science and Mathematics Teaching Center - The Third Decade") and its relation to current needs and to the outline of the directions provided in my paper. The analysis workshops are scheduled for both before and after lunch. There are three parts to the luncheon program. There is a recognition of contributions that you have made to the Center in the past, and a recognition of the past Directors. There will be a presentation by William Kolomyjec on Computer Generated Art and I will also give some directions and instructions for the afternoon sessions of the analysis workshops. In the late afternoon there will be a panel discussion evaluating our priorities for the decade ahead. The six panelists, three university people and three school people, will react to my "third decade" paper and to the inputs from the analysis workshops. Finally, there will be a closing address by Bob Silber, the Executive Director of the National Science Teachers Association. If you haven't met Bob, I will provide an introduction to him later in the day. Just for now, so that you will know who he is, Bob, would you stand?

Following the Conference, tonight at 6:00 p.m. there is an invited dinner for the people who have worked on the program, including the staff of the Science and Mathematics TEaching Center, the discussion leaders, the authors, the rapporteurs, the graduate students, the panelists, the speakers, and the donors.

What will be the outcome of this Conference? The papers will be reviewed and revised by the faculty of the Science and Mathematics Teaching Center in light of the results of the analysis workshops, the panel discussion, and other input from the participants. We also encourage you to provide us with additional written reactions to the papers presented.

The papers will be published in a Twentieth Anniversary Publication which will be widely distributed. We have set meetings for next Tuesday and Wednesday to consider the results of these analysis workshops and other input and to incorporate them into our planning.

This Conference is important to us. We think it is going to help us set our directions in important areas for the next decade's work. We appreciate your input and we are very glad that you were able to attend.

Without further delay, I would like to move to the keynote address. In considering the selection of the Keynote Speaker for our Twentieth Anniversary Conference, the staff deliberated only briefly. The best person to talk about the past and future of Science Education was already here at Michigan State. Coming to M.S.U. in 1963 from the University of Chicago, he has distinguished himself as a leader in many fields. His book on Learning by Discovery, a landmark known to everyone here, has been translated into French, Spanish, and Japanese. His studies on medical diagnosis and how it may be taught to future physicians are already milestones in medical education. His work ranges from Head Start, to the World Health organization, to the Handbook of Research on Teaching, of which he is an invited contributor. He is currently Co-Director of M.S.U.'s Institute for Research on Teaching, an organization which promises to have major impact on the research being done on the teaching/learning process. During the past 17 years, our speaker has continually been "where the action is" in education; in mathematics education, in science education, in the application of learning theory to instruction, and in research on teaching. His current work promises to continue to be one of the pacesetters in our profession. I am most pleased to introduce our keynote speaker, Dr. Lee Shulman.

SCIENCE AND MATHEMATICS EDUCATION -- RETROSPECT AND PROSPECT

Lee S. Shulman
Michigan State University

and

Pinchas Tamir
Hebrew University, Jerusalem

SCIENCE AND MATHEMATICS EDUCATION : RETROSPECT AND PROSPECT

Dr. Lee S. Shulman and Dr. Pinchas Tamir

As we examine the past and the future of science and mathematics education from the perspective of this 1977 celebration of the Twentieth Anniversary of the Science and Mathematics Teaching Center's establishment, we confront a starteling paradox. On the one hand there has rarely been a time when evidence for the importance of science education and, more important, scientific and mathematical literacy among the general population has been easier to demonstrate. For example, President Carter's first trip to Europe was dominated by discussions, neither of alliances nor economics, but of energy and nuclear proliferation. Correspondents for the television networks attempted desperately to exaplain the problems of breeder reactors to the American public. Elections in our decade are won or lost, especially in the western states, on the candidates' position with regard to ecology, environment, ane energy issues.

More recently we have seen arguments on the safety of basic research in genetics move from scientific assemblies to legislative assemblies such as the city councils of Cambridge, Massachussetts and Ann Arbor, Michigan. City councilmen not specifically trained in science now argue about potential mutations in a tiny organism called E. Coli, a permanent resident of each of our intestinal tracts. These councilmen debating about whether to permit recombinant DNA research in their localities may have as much to say about the future of investigations in this frontier of molecular biology, as does the National Academy of Sciences.

With all such indications of the need for scientific literacy, public clamor for more teaching of science and mathematics is not apparent. The cries of "back to basics" rarely include science and stress computation, nor mathematics. Thus, we find ourselves in 1977 confronted with the paradox that while we need to know more science in order to live in and run our society, we, the American public, appear unwilling to invest the resources of our time, energy and the activities of our teachers and students in the pursuit of excellence and understanding in the fields of science and mathematics.

It is with this paradox in mind that we approached our very general review of the fields of science and mathematics teaching over the twenty years since the creation of this Center in 1957. We especially focussed on the 7 years since our last joint review (Shulman and Tamir, 1973).

1957 was a very interesting year. It was, in many ways the dawn of several revolutions. Although there were earlier math education developments, 1957 signaled the birth of the curriculum development revolution in this country. We can look back on that revolution and examine it in terms of the four commonplaces of education that Joseph Schwab, a distinguished science educator, elaborated in his Inglis Lectures on the teaching of science as inquiry (Schwab, 1962), namely: the subject matter or curriculum, the learner and the processes of learning, the teacher and the processes of teaching, and the milieu or the context.

Subject Matter

The revolution in curriculum development rapidly brought subject matter specialists into the field of science education. Names like Zacharias, Beglè, Karplus, Davis, Schwab and Holton, who were leaders in the disciplines, became senior partners overnight in the process of curriculum development in the sciences and mathematics. An insightful paper by Bridgham (1969) anticipated one of the problems that was to occur because the scientists and mathematicians who came into curriculum development often brought with them a diversity of conceptions of science and mathematics which were not always totally clarified before they were translated into curriculum materials. All of us reaped some of the consequences of that ambiguity in the ensuing years as we attempted to deal with these curricula.

The Learner and Learning

1957 also signaled the movement of another group, in addition to the subject matter specialists, into science and mathematics education -- the psychologists. They came along with the subject matter specialists and introduced a decade of discovery learning, inquiry, higher order cognitive processes, task analysis and individualization. By and large, it was a group of psychologists who had never before worked on classroom instruction. These psychologists included Piaget, who did not work personally on the new curricula but whose name was always invoked with great solemnity in the defense of almost anything; Barbel Inhelder, his collaborator, Jerome Bruner, Robert Gagne, David Ausubel, and many others. These psychologists brought with them two major messages: one was an emphasis on the cognitive processes central to school learning, as represented by the centrality of discovery and inquiry in many of the new curricula. They also heightened interest in individual differences among students, especially individual differences in learning rate or aptitude and the need to develop programs or curricula that could be adapted to those. We thus began generating a series of programs, some of which were oriented toward the cognitive and discovery processes (BSCS, PSSC, SCIS, ESS and the like), and others, which developed a bit later, and were more oriented toward the individualization of instruction: IPI, ICE, ISIS and others.

A remarkable coincidence of timing between the 1957 beginning of the curriculum revolution and a 1957 beginning of a revolution in the field of psychology is worth noting as well. 1957 was an incredible year for psychology. Within 12 months of the creation of this Center, the following developments occurred in the field of psychology:

> A book by Bruner, Goodnow, and Austin was published (1956) entitled A Study of Thinking, one of the first and still most influential books on the experimental study of concept learning, which used that word "thinking," considered almost obscene in psychology since the death of the Würzberg school almost fifty years earlier.
>
> George Miller (1956) wrote a paper on the magic number 7 plus or minus 2 that signaled an interest of psychologists in problems of memory capacity, especially short-term memory, and heralded the beginning of information processing psychology.
>
> This emphasis was echoed during that same year by the work of Newell, Shaw, and Simon (1958) on information processing models in proving mathematical theorems, a paper that has itself served as the basis for almost all of the information processing psychological research in education since then.
>
> An obscure young linguist at M.I.T., Noam Chomsky (1956), published Syntactic Structures, which has nearly sabotaged what was then the mainstream of experimental psychology.

A few years later Miller, Galanter, and Pribram (1960) collaborated on Plans and the Structure of Behavior, which attempted to summarize and coordinate the then infant work on computer-based information processing models and developments in transformational grammars into a single theoretical model.

Bruner joined this group of psychologists with subject matter specalists at the Woods Hole Conference, and then wrote Process of Education (Bruner, 1960), based loosely on the deliberations of the conferees. Barbel Inhelder contributed an entire chapter of the book on her work with Piaget, whose perspective had not previously been central to curriculum development.

Within a year, J. McVicker Hunt published Intelligence and Experience, which attempted to demonstrate, and in many ways did so convincingly, that one could take the information processing model on one hand, and the cognitive developmental model of Piaget on the other, combine them, and have a meaningful theory of intelligence.

The coalition between the psychologists and the subject matter specialists was an interesting one. Robert Davis (1977) observed that there was an unstated agreement between the psychologists and the subject matter specialists: The psychologists deferred to the subject matter specialists entirely with respect to the judgments about what was worth teaching. Even when the

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topics that subject matter specialists insisted were worth teaching struck the psychologists as inappropriate, the psychologists remained silent. On the other hand, the subject matter specialists deferred entirely to the psychologists with respect to "how do you get this stuff into the heads of the students?" He characterized their working relationship by a pipeline metaphor: The subject matter specialists decided what went into the pipe and the psychologists constructed the conduit for getting it into the curriculum. Teachers and science educators typically were those at the other end of the pipeline, who translated the curriculum materials into operational programs. It was a strange coalition and in many ways we may have paid a price for respecting each other's turf much too seriously, when we all had sufficient good judgment to raise germane questions about each other's work.

There was yet another irony for which we have paid a price. Most of this curriculum development, primarily funded by NSF, had a strong cognitive discovery orientation, and by law required evaluation. Though not an unreasonable requirement, in principle, it became ludicrous in practice. The evaluation models regnant in the 60's derived from a totally different corner of psychology and education from the underlying cognitive models of those curricula. Thus, a set of curricula rooted in theories of cognitive development, cognitive learning, discovery and inquiry in students, was being evaluated with an evaluation technology characterized by the performance objectives and task analysis of neo-behaviorism. By and large, those evaluations found the new curricula only equivocal in their impacts. There may, however, have been an ironic mismatch between the ideology that produced these curricula and that which directed the evaluations.

Milieu

The sudden clamor, after Sputnick, for the creation of a new elite of scientists and engineers to compete with the Russians, was the source of much of the curriculum development. But in many ways there was a misreading of the milieu. The curricula developed on the assumption that the social needs of the time were stable and unchanging. A few years later, high school and university students of the late 60's and early 70's were to shock us into recognizing that this was an error. Indeed, in a paper called "Process of Education Revisited," Bruner (1971) partially recanted and apologized for having failed to realize that this society, the political and social context of education, was unlikely to remain stable.

Within the community of mathematics and science educators we began to observe reactions to the elitism of the earliest of the new curricula, perhaps epitomized by the response to PSSC embodied in Harvard Project Physics. Later a variety of new programs reflecting a growing concern for the needs of the society emerged. Several different but related trends characterize these new programs: (a) integrated, interdisciplinary approaches with a focus on social and environmental issues; (b) more emphasis on attitudes and values as related to science; (c) courses dealing with applied aspects of science with a growing recognition that although technology is not science, it is closely related to science and deserves appropriate treatment in the context of learning science; and (d) special programs to meet the needs of minorities and culturally disadvantaged students.

The Teacher

Interestingly, while modes of teaching received a great deal of attention from those who developed the curricula, with emphasis on the laboratory, student experiments, "invitations to enquiry," individualized instruction, and a variety of technologies, the teacher qua human being, responsible for operating this "subject matter-technology-individual student" complex, received little attention.

We made much of the fact that every summer our NSF workshops brought teachers to our campuses. To be sure, for those teachers it was an exciting experience. Contributions were made which helped teachers make the programs more realistic, more understandable, and more successful. By and large, however, the central role of the teacher to a program's success, and the importance of continuous teacher support, was very much at the bottom of the priority list during those years. If you examine the chapter we wrote in 1970 (Shulman & Tamir, 1973), "Research on Teaching in the Natural Sciences," you will have a hard time finding reference to the study of teaching and teachers. There was a feeling that if you could get the curriculum into shape, package it well, and find the right technologies of the laboratories and individualization, teaching would take care of itself. We have learned differently. In fact, as we shall see, though much ignored in the history of science education, questions of teachers and teaching will be central to the future of the field. The teacher is the key to the adaptation and implementation of existing curricula. For example, Passow (1976), discussing the future of secondary education, argues that the major thrust of schooling should place society itself as the core of the curriculum. Yet he is quick to admit that, with whatever changes we hope to make, we must recognize the supreme importance of those working at the "grass roots" in effecting change.

Prospects for Science Education

We would like to review some of the ways in which, were we to write our chapter on the teaching of natural science today, we would write it differently. We shall point out some of the ways in which the field of science education has changed even over the last seven years and what these changes seem to suggest for the future.

Curriculum Development

Funding for curriculum development at the national level is finished. An era is over. It is over for a number of reasons. First, because that effort did not accomplish what we expected. It did not revolutionize life in classrooms. Somehow, when the curriculum reached the classroom, it did not coincide with those dreams we shared at its creation, when all of us, as teachers, scientists, mathematicians, teacher educators, and curriculum specialists created those beautiful programs.

Another reason for the end of the era is that, for now, we are inundated with curriculum. We have curriculum materials, modules, packages, kits, in greater number and variety than any single school system could possibly incorporate. For the moment, investment in large-scale national curricula is not in order. Moreover, our experience with studies of implementations of these curricula has made it clear that the key to successful curriculum development and application in the schools is an understanding of how one adapts national or broad-scale curricula to local conditions. Adaptation occurs whether or not it is planned, so it had better be anticipated. This is one of the exciting new developments in the field of science and mathematics education, a shift of focus away from centrally organized curriculum development and towards curriculum use, adaptation and implementation.

It is not surprising that most of the work on implementation of curricula to local conditions has been conducted in foreign countries, where it was recognized that you could not take BSCS, SCIS, or Sesame Street and merely translate it for use in Israel, Mexico, England or France. You had to adapt and make modifications. For this you needed guidelines, conceptual models, schemes for decision-making, technologies for analyzing programs and identifying their important features; and then you needed to translate them into materials that were appropriate for local conditions, national needs and interests, learner characteristics, the particular structure of the curriculum in which they were to be embedded, and the like. Three schemes for such curriculum analysis have recently been developed (Allen, 1976; Blum, 1976; Ben Peretz, 1977). The scheme developed by Blum has been used in the exchange of science programs between Hawaii and Israel.

Kilpatrick (1977) has reported the work of Limmec (1977) on the concept of curriculum "half products." Curriculum developers are encouraged to develop incomplete curricula which cannot be mindlessly incorporated or assimilated into a program even if teachers were so inclined. It is almost like those records which allow you to play a Beethoven piano concerto along with the Philadelphia Symphony Orchestra. If you don't play the piano, you hear the concerto without a piano, which is far from satisfying. These half products that are created fully enough that a teacher can complete them by working on and manipulating them; but he must do that before the materials are ready to use. We find this a fascinating idea in curriculum development! Like other new ideas it needs research on (a) how teachers *can* complete the materials, (b) how they *do* complete the materials, and (c) how they can be *trained* to complete the materials.

We are beginning to see that kind of research emerging here in the M.S.U. Science and Math Teaching Center. Smith is studying science teachers as they plan units of instruction which frequently require the adaptation of curriculum materials to a plan for instruction (Smith, 1977). Shroyer's studies of mathematics teachers also have that flavor (Shroyer, 1977). Much of our work in the Institute for Research on Teaching examines teacher planning in reading, language arts, mathematics and general classroom management (Shulman and Lanier, 1977). We would predict that in our field of science and math education, curriculum research will experience a renascence, this time at the level of the interface between the materials and instruction: namely, studies of teacher planning and teacher development of instruction, using as sources the many kinds of available material and then adapting them to fit with the teacher's assessment of learners' characteristics, community interests, and needs of the school's overall general curriculum.

Science as Inquiry and Teaching by Inquiry

An important curriculum issue is a continuing confusion, as we see it, between teaching science as inquiry and teaching by inquiry. That is an issue one of us struggled with in the *Learning by Discovery* volume 11 years ago (Shulman & Kiesler, 1966). We addressed it subsequently (Shulman & Tamir, 1970) and as far as we can tell it is worth reiterating today since there remains a confusion between the two concepts. As emphasized by Schwab (1962).

> The phrase "the teaching of science as enquiry" is ambiguous. It means, first, a process of teaching and learning which is, itself, an enquiry, "*teaching* as enquiry." It means, second, instruction in which science is seen as a process of enquiry, "science as enquiry." Both of these are parts of the idea in its complete form ... . .Of the two components -- science as enquiry and the activity of enquiring -- it is the former which should be given first priority as the objective of science teaching in the secondary schools (pp. 65, 71).

Unfortunately, although 15 years have passed since this distinction was made, there is still a tendency to equate teaching by inquiry with filling the science curriculum with activities that look like inquiries. One of the consequences of this has been the continued misuse of what is probably the hallmark of science education, the laboratory.

The Laboratory

In our earlier chapter we used the work of Schwab (1962) and Herron (1971), among others, to indicate that there was a "rhetoric of inquiry" in science education admonishing teachers and curriculum makers to teach students to solve problems and think. Ostensibly, the laboratory was set up as the vehicle for teaching problem solving in the new curricula such as BSCS and PSSC. However, the overwhelming proportion of those labs provided the student with a definition of a problem, gave him the set of procedures to employ and frequently gave him the key against which to check his answers. Some inquiry! We fear that much of that continues to occur though the direction of recent research on the science laboratory may provide needed guidance to redress that balance.

More precise and careful studies of learning in the science laboratory are being pursued. Much finer grained analyses of the kinds of learning to be undertaken and the kinds of instruction that in fact occur, are now being conducted (Hegarty, 1977; Kyle, 1977; Penick, 1977; Shymansky, 1977; Tamir, 1977). There are studies examining specific issues such as the extent to which the nature of directions guide and influence student observation in laboratories (Kempa & Ward, 1975), or the cognitive and affective outcomes of substituting filmed experiments for actual laboratory work (Ben Zvi, Hofstein, Samuel & Kempa, 1976a and 1976b). We also find, and this is for us a most important observation, that a major ingredient in laboratories necessary to transform them from parodies of inquiry, where students simply go through the motions and the imitation of science, to bona fide inquiry, is the pre-lab and post-lab discussion (Tamir, 1977). It has become very clear that only when this kind of active manipulative laboratory work is followed by active discussion may these activities achieve their promise as true inquiry activities. As Woodworth and Dewey and others pointed out to us many years ago, we learn not by just doing, but by thinking about what we are doing. Inquiry in science and mathematics cannot be achieved merely by doing, and the thinking about what we are doing must in most cases be teacher-directed in a small or large group setting. An important development in this respect are the materials for teaching science by inquiry through discussion of original research papers (Connolly, Feingold & Walshtrom, 1974).

The importance of discussions is not only for laboratory work in science, but also for those kids sitting individually in carrels working at exercises. So much of that work is never consolidated, never brought together, never elaborated, and never related to anything else.

Individualized Instruction

Individualization remains one of the major trends in American education. As mentioned before, programs like IPI, ISIS, IGE at the precollege level and PSI (Personalized Systems of Instruction) at the college level have by and large taken over many science courses. For the same reasons we advocated caution about the laboratory when it is not followed by opportunities for discussion, consolidation and critical examination, caution must be exercised with individualized instruction. Research at the Open University in England (a university of 50,000 students that teaches by correspondence and television) has repeatedly reported that students pass individual unit diagnostic tests quite successfully, but when they sit for the final exam, 50% of them fail (McIntosh, 1977). They have learned the pieces but have never had an opportunity to put them all together. A fascinating series of case studies done by Stanley Erlwanger (1975) at the University of Illinois on learning of mathematics in an IPI curriculum report similar findings. Some students who were considered among the top 25% of a class and who had successfully passed one unit test after another were interviewed clinically to probe what they really understood. Some were found to have developed weirdly idiosyncratic algorithms for passing those tests. They had simply come up with ad hoc, inconsistent, and inaccurate mathematical theories and rules which somehow got them through those units, but led to a totally distorted understanding of mathematics. It was apparently in the nature of that individualized program as there implemented, and it may well be true of almost all the individualized curricula, that if a pupil scores well on unit posttests, she rarely talks to anybody about it. The teacher doesn't talk to her. The aide doesn't talk to her. The aide typically scores these tests. Apparently, if there are errors, the kids pick up cues from the aide to see what would be the right answer, then run back and redo the posttest.

The results of Erlwanger's research are frightening because they again highlight a perplexing problem in education, a characteristic of most practical arts. Although individualization solved some problems in science and mathematics instruction, it created (unintentionally but quite predictably) a new set of problems that may, in the long run, be more serious than the problems it was supposed to solve. Clearly we need some sort of proper blend. We need not forego the fruits of individualization, but we cannot countenance the bitter fruits among them. Teachers must learn both to employ the techniques of individualized instruction and to return to teaching again. They must return to active interaction with groups of students with whom they directly discuss the materials of instruction, taking responsibility for explaining, coordinating and consolidating that understanding once the immediate experience and acquisition of knowledge has been achieved within the laboratory or the individualized carrel. It is simple to make such assertions about teaching; it is quite another thing to recognize the responsibilities the assertion places on teacher educators to prepare teachers to accomplish that very difficult task.

Piaget and Science Education

An examination of the latest NARST meeting presentations shows that Piaget and Piagetian studies continue to dominate research on learning in science and mathematics. We find three types of investigation: (a) attempts to replicate Piaget's studies with new samples or new tasks and to develop new measures for locating a person at a particular developmental level; (b) attempts to demonstrate acceleration of transition from a lower to a higher stage in the form of training experiments; and (c) application of Piaget's concepts or methods to anticipate cognitive difficulties students may encounter in learning certain concepts in science or mathematics. We would like to indicate, as we have in other places, that in our opinion those Piagetian studies included under categories (a) and (b) above are typically irrelevant to science education. The irony is that Piaget's clinical method originated as an alternative to some of the mindless use of the quantitative - experimental paradigm in research on instruction which may be described as: "Grab two groups, do something to one of them, lock up the other, run your ANOVA and . . ." What seems to have occurred is a similar misuse of the Piagetian paradigm. Instead of "grab two groups," it is now "find three kids, one of each age."

The approach is unproductive for several reasons. If you look at the problems of science education they are different from the problems addressed by Piaget. Most of Piaget's work is focused on the problem of vertical decalage, of mapping developmental stages over time, longitudinally, as the child grows. By and large those are not the problems in science education. The goal of science education is not to move children into concrete operations. They are going to get there anyway. The major problems of science education are those horizontal decalage, enriching and differentiating student understanding within a level of development. Piaget has little to say about that. Not because he is a bad psychologist -- that is just not his problem. Yet people have latched onto Piaget's methods and his research paradigm, and for 15 years have been beating science and mathematics research to death with it.

Science educators should view Piaget in perspective (Doyle & Lunetta, 1977). While we need no more studies in categories (a) and (b), we welcome studies of category (c) in which are studied concepts in science and mathematics that are intrinsically important to those who would develop curricula in those fields. Fine-grained analyses are conducted of those concepts and the conditions for their development. Then, studies are conducted on instruction in those fields (Smith, 1977). You do not begin with concepts merely because Piaget or his disciples judged them important; you begin with concepts you have selected because they are central to curriculum in the teaching of science and mathematics. You may see an example of this in a recent study by Nussbaum and Novak (1976) on the development of the concept of the Earth in young children. It is hard to think of an elementary curriculum in science which at some point will not deal with a concept like the Earth. Children are asking about it all the time. But the concept of the Earth has no intrinsic importance to a cognitive developmental psychologist. He is concerned about and can make use of a concept like conservation, but conservation is not of any particular importance intrinsically to science education. It may have some relevance, but not as much as one would infer from how much we study water-pouring in our research literature of science and mathematics teaching. As observed by Klausmeier (1977):

> Children appear to acquire concepts and other outcomes in the cognitive domain gradually, rather than abruptly, although qualitatively different cognitive operations are presumed to emerge which make possible successively higher levels of concept attainment . . . .Focused instruction clearly aids students to attain concepts to successively higher levels during short time intervals and also to use their concepts in understanding principles and in solving problems . . . . The quality of educational experience exerts a strong influence on both the rate and the final level of cognitive development (p. 179).

Evaluation

In the past seven years we have witnessed two trends working in opposite directions. On one hand we observe the growing emphasis on accountability which requires more testing and more evaluation. On the other hand, we experience a growing distrust among educators in the various forms of assessment carried out in schools. These assessments, which rely heavily on paper and pencil standardized tests, are often considered unidimensional and simple-minded, incapable of tapping into what competent educators are trying to achieve in science and mathematics teaching. While we agree that new approaches to evaluation are badly needed, we would like to suggest that a number of such approaches have been developed (see Shulman & Tamir, 1973; McGuire, 1976; Educational Development Center, 1976). It is, therefore, possible to design evaluation systems which will provide the information required by those who seek accountability, but at the same time will make constructive contributions to the evaluation of learning and instruction.

The Israeli matriculation examination in biology is a case in point. All 12th grade students in Israel take the national matriculation examinations at the end of their high school studies. These examinations are similar to the O and A level examinations in England and a certain minimum score is required across a certain number of subjects as a prerequiste for university admission. In biology the exam was typical of European matriculation tests. It was a test of knowledge, and lots of it. When the Israeli adaptation of the BSCS was introduced in Israel, it was realized that an alternative form of the biology matriculation exam for BSCS students should be developed. It was further recognized that the exam was not merely a test of achievement but potentially the most powerful form of influence on curriculum. Instead of securing the exams, within a couple of months after each administration, all the items and practical exercises are published and made available to the teachers, who soon realize that it is not so bad to teach for the test. Both teachers and students know what the test is like, and they find that the best way to prepare for it is to study biology as inquiry, to solve problems in the laboratory, to analyze research papers, etc. (Tamir, 1976). This is an example of how one may reconcile the accountability system and the instructional program. Our message is clear: somehow gain control of either the assessment program or alternatives within the assessment programs. Do not fight accountability — we all are accountable and should be. But do not allow yourselves to be held accountable for things you neither teach nor intend to teach. Accountability programs can work in favor of curriculum innovation.

Recent research (Bennett,1976) contrasting formal and nonformal education in England had as one of its most striking findings that, while formal education (as there defined) led to higher average academic achievement in traditional senses than nonformal education, the schools that had maintained the 11-plus exam, whether formal or non-formal in their orientation, achieved more than those that did not. There was something about that externally mandated assessment that apparently had more influence on what teachers taught and students learned than whether they had chosen to teach in a formal or non-formal manner.

Teacher Education

The preparation of teachers will be of growing importance in the coming years. We have laid out the argument for that already. We are beginning to see the development around the world of teacher education materials specifically for preparing science teachers. This is consistent with the general trend away from conceiving of teaching as something generic across subject areas toward the recognition that teaching is subject-matter specific in many important senses. We can find the STEP (Science Teacher Education Program) in England, the ISTEP program in Israel, the ASTEP in Australia and the UPSTEP in Iowa. All these programs share the recognition that teachers must be trained to mediate between curriculum alternatives as they are packaged in central development agencies and what the teacher has to do in the classroom. The concept of half-product curriculum units will fit well into these programs. In general, we will not be able to train teachers by admonition or by theory alone to engage in curricular synthesis and development of this sort; we must conduct

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systematic studies of the methods used by teachers who are effective in planning and executing curriculum adaptations and then teach others to do it as well. By and large this work will be done more with teachers already out in the field than with preservice teachers -- in part because many present inservice teachers will be teaching for the next thirty years, and in part because it is very difficult to teach someone who has had only preservice teaching experience how to adapt curriculum to the exigencies of the classroom. This may necessarily be an inservice continuing professional development activity. We can already find models of that kind of work in the Science and Math Teaching Center (McLeod, 1977).

The Future

What does the future hold for science and math teaching? We regret that we have to conclude on a pessimistic note, with a word of caution and warning. If the signs we see are accurate, problems lie ahead, especially for the field of science education.

In recent years we have witnessed an increasing demand for education in "the basics." Most teachers and administrators will probably interpret that demand as calling for more instructional time on the tasks of language acquisition, reading, writing, and basic arithmetic calculation skills at the expense of "less essential" areas such as science and the social studies. There is a real danger that many of the efforts made in the 1960's to improve and enrich science education will be wasted simply because less science will be taught in the elementary schools.

The increasingly frequent research findings documenting what appears to be a direct relationship between engaged learning time and academic achievement (e.g., Bloom, 1976; Rosenshine & Berliner, 1977; Harnischfeger & Wiley, 1976) will further exacerbate the trend. When students have failed to "master" some basic skill, the time for remediation and relearning must perforce be taken from a "less basic" subject.

It is therefore highly important to make educators and the public aware of the qualities of science instruction as a means for developing basic skills, both in language and in arithmetic. A number of studies have pointed at the potential of science for the teaching of language, reading and writing. Rowe (1970) found that the amount of student-initiated content-relevant speech in ten Harlem classrooms was 200 to 500% higher during science classes than during language arts classes. Similarly McGlathery (1968), Ayres & Mason (1969), Huff & Languis (1973), and Renner & Coulter (1976) have all found that young children involved in activity-based science courses make considerable language gains. The nature of the interrelationships between the learning of science and language remains unknown. We are only beginning our efforts to understand how some of the same cognitive mechanisms involved in learning science operate on the learning of language. Quinn & Kessler (1976) found that as children improve in creating and formulating hypotheses, their language becomes syntactically more complex and this happens without any direct effort to teach language. Thus there appears to be a cognitive link between the ability to make scientific hypotheses and language development.

An entirely different kind of relationship was argued by Thier (1976), who writes:

> To read successfully the child must be able to discriminate between words that are alike and words that are different.

> Seeing a sequence of letters within a word, having a left-right concept, position-in-space concept and directionality concept, must be developed as well as a good visual memory . . . . Carefully related science experiences can be used effectively as an alternate approach for developing visual perceptual skills (p.39-40).

Newman (1975) suggests another reason for why "you don't have time not to teach science." He observed that children who are initially unsuccessful in their achievement in reading and writing in regular language arts lessons continue to fail as they progress through school. He found that science could help a variety of youngsters who do not achieve success in regular programs to achieve some success in school, thereby leading to higher motivation and higher achievement overall.

Not only may learning science for its own sake play a significant role in upgrading the learning of language. One may also wonder whether science teachers can make some explicit efforts to use science experiences as a vehicle for upgrading language skills. Suggested activities may be found in the "List of Creative Writing Themes that Can Be Coordinated with Various Science Units" (Reid & McGlathery, 1977) as well as in experimental programs like "Integrating Science with the Creative Arts in Career Education" (Yae & Kelly, 1975). More research and development are needed to provide a basis for systematically using science in upgrading reading and writing.

Parenthetically, an interesting research question is whether we can improve language performance if we increase the use of essay tests in science (and other subject areas) to, say, 50%. At present, there are high school graduates in the U.S. who have never taken a test other than multiple-choice.

It should be clear that the claims we make for the value of science in the cure of reading and writing ills probably hold for other subject areas as well. A fascinating study by Crano (1976) and his co-workers will illustrate this point. A group of high school students who were retarded in reading performance were given experience in reading charts and graphs as part of a summer remedial experience which also included conventional reading improvement exercises. Their post-test scores were substantially higher than those of a control group who spent more time overall doing more reading exercises. That may seem sensible, but those who control the curriculum and accountability systems will not revise those programs until more research is carried out to explicate the complex relationships among time-on-task, fatigue, boredom, specific inter-task transfer, etc.

Another interesting question is to what extent we can take advantage of the fact that the learning day is essentially the whole waking day -- not merely the five or six hours of the school day. Within the community we have some extraordinary resources, such as television and museums, that may be more powerful tools for learning science than anything we can come up with in our 40-minute laboratory periods in the schools. But as long as we consider the walls of the schools the boundaries of science education, we will fail to take advantage of such possibilities for increasing the scientific literacy of our population.

Finally, one of the ways science and mathematics educators can win is by being willing to lose. Joseph Schwab (1974) argued that for the sake of the future of science education, science educators ought to be prepared to forego control over half of their presently alloted curriculum time and to contribute that half of their time to new integrated curricula that would cut across subject areas. He did not base his argument on the research literature on transfer or on the political reality that, whether you give it up or not, you are going to lose it. He was arguing on the basis of the concept of curricular integration, a concept he and many other curriculum specialists have argued for years, and one which we now must revive. One of the saddest funerals of the past year was the funeral for USMES. USMES represented precisely the kind of integrated science, mathematics, social studies curriculum which could have been and may yet become the prototype for what Schwab and others are recommending. Such a prototype could redound to the greater benefit of reading comprehension and all the other basic skills if we could implement it. Programs like USMES demand teacher preparation and inservice teacher education. USMES was scuttled by NSF because it was not a proper curriculum, capable of standing alone as a package. In the words of the NSF critics, it was more reminiscent of a philosophy of teaching than a curriculum. Apparently it required too much commitment and thinking from teachers to be judged a suitable curriculum.

If programs like USMES are allowed to die, then shortly, because of the conditions we have described above, science and mathematics education as we know it may also die. They will be relegated to activities engaged by those elite students who master their objectives early, while the others are receiving most of the teacher's help on the basics. Unless we take initiatives, in research and development and teacher education to foster curriculum integration and instructional collaboration, we will find that science and mathematics teaching will join life-adjustment and core curriculum as poignant footnotes in the history of twentieth century education.

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THE SCIENCE AND MATHEMATICS TEACHING CENTER:
A RETROSPECTIVE VIEW

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THE SCIENCE AND MATHEMATICS TEACHING CENTER:
A RETROSPECTIVE VIEW

Dr. Frederic B. Dutton
and
Dr. Julian R. Brandou

The start of Spring term, 1977, marks the twentieth year of operation of the Science and Mathematics Teaching Center (SMTC) at Michigan State University. A complete history is beyond the scope of this paper, however, a brief account of the origin of the Center and a discussion of some major activities is included, and a condensed chronology is appended.

Many individuals have contributed to the Center and its programs. Faculty members, both from MSU and other institutions; the secretarial staff; the core of graduate students and doctoral candidates in science education; and school and industrial people have all provided important input. Some of these have appeared on the payroll records of SMTC. Others have made significant contributions of time and energy over an extended period, though they may have been supported by another department or a grant. Though some directors and staff are noted in subsequent sections, special recognition is due Dr. John M. Mason, Dr. Jane Smith Elliott, Dr. Clarence Schloemer, and Dr. Charles R. Peebles for their contributions. Also Dr. T. Wayne Porter, Dr. Frank Peabody, Dr. Roger Hoopingarner, Dr. Fred Stehr, Dr. William Drew, Dr. Donald Dezeeuw and Dr. W. D. Collings, of the Biological Sciences Admission and Advisory Committee, Drs. Sherwood Haynes, Jack Kinsinger, Robert Hammer, and Andrew Timnick, department representatives. Drs. John Wagner, Isobel Blyth, Lauren Woodby, William Fitzgerald and Glenda Lappan, of the Department of Mathematics, and

Drs. William Walsh, Shirley Brehm, Perry Lanier, Calhoun Collier, and Bruce Cheney, of the Department of Elementary and Special Education. A more complete listing of faculty and staff is appended.

ORIGIN

On March 1 and 2, 1956 at a meeting of the American Association for the Advancement of Science (AAAS) Cooperative Committee on Science Teaching in Ann Arbor, Dr. T. Wayne Taylor of the University of Texas showed Dr. Dutton a brochure describing the activities of the Science and Mathematics Teaching Center at that University. This crystalized the possible solution to a set of problems which some of the Chemistry Department staff had been concerned about for some time.

> High school teachers once certified and employed were isolated from their disciplines. In most high schools there was but one chemistry or physics teacher. Teacher's meetings and inservice training sessions were addressed to problems concerning the whole school and offered little help to those whose special function was to teach in science or mathematics.
>
> Colleges of Education were offering professional education courses in summer sessions and during the year in extension centers but these spoke to only one facet of the science and mathematics teachers responsibilities. Parallel content courses in the disciplines were almost non-existent.
>
> The information explosion had made it impossible for one individual to single handedly search the literature for answers to student's legitimate questions and to be able to direct them to useful references. Those teachers and/or students who took the time to address an inquiry to "The University" received a "brush off", a useful answer, or more than they wanted to know, depending upon the desk which became the ultimate repository of the inquiry.

Efforts to ameliorate these problems became a charge to the SMTC in Vice President Hamilton's recommendation for Board action and were detailed in the fourteen functions outlined in the Center's brochure.

After discussions with Dr. Lawrence L. Quill, Head of the Chemistry Department, and others, a letter was sent to Dean Milton Muelder of the College of Science and Arts and to Dean Clifford Erickson, Dean of the

College of Education, signed by Drs. Quill and Dutton, suggesting the establishment of a Science and Mathematics Teaching Center at Michigan State University. Ultimately the recommendation was sent to the State Board of Agriculture and approved on December 28, 1956. The Board Action reads as follows:

> "The State Board of Agriculture at its meeting December 28, approved the recommendation that effective April 1, 1957, Professor F. B. Dutton of the Chemistry Department be designated Head of the Science and Mathematics Teaching Center to be jointly responsible to the Dean of the College of Science and Arts and the Dean of the College of Education. Professor Dutton will have the responsibility for encouraging and promoting better science teaching in the State of Michigan and to facilitate preservice and inservice training programs for science teachers, and such other responsibilities as are agreed upon from time to time by the Dean of the College of Education and the Dean of the College of Science and Arts."

The Center began operations in Room 200 Kedzie Chemical Laboratory with a Head* and a secretary. At the end of the Spring term, when the space was finished on the fourth floor of the University Library, the Center moved into Room 403. A year later, when the College of Education Building was completed, the Center moved into more spacious quarters in Rooms 517 and 518 on the fifth floor of that new building.

Dr. T. Wayne Taylor joined the SMTC staff in the Fall of 1959 and the SMTC moved again, this time to Room 513 and 515 at the west end of Erickson Hall. The growth of the Center paralleled in many ways the growth of the College of Education and by the early '60s space was again at a premium.

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*In 1962 the previously used title "Head" was changed to Director.

It was suggested that the Science and Mathematics Teaching Center might move to the new residence hall which was already under construction on the east edge of the campus. Dr. Julian R. Brandou, who joined the first MSU Traveling Science Teacher Program, remained on the campus, completed his Ph.D. degree and had joined the Center faculty in 196[illegible] as an Assistant Professor, worked with the architects to adapt the available academic areas for SMTC purposes.

The requirements for science teaching required some modifications in the plans to provide for demonstration facilities in the Kiva and laboratories on the lower level. These were implemented and the Center moved into the offices on the second floor of the east connecting corridor when the building was opened in 1963. Teaching laboratories and preparation space were provided on the lower level surrounding the snack bar area and in five classrooms on the first floor surrounding the Kiva. The classrooms were shared with the University College classes scheduled there for the convenience of the resident students. The Director was assigned the responsibilities of academic officer for the building which was subsequently named McDonel Hall.

The addition of the new introductory biology sequence for the College of Natural Science to the responsibility for biological and physical science instruction for elementary teaching candidates in the College of Education overloaded the academic areas of McDonel Hall. It was determined that the academic area in east campus residence hall number 5, then in the planning stage, would be assigned to the Science and Mathematics Teaching Center. Once again, Dr. Brandou was called upon to work with the architects and for the first time, facilities were designed for the academic program to be housed in a living-learning unit prior to construction. In 1965 the offices for the Center administration, some faculty, and the teaching program in the physical sciences were moved to Holmes Hall, and the biological sciences instructional program expanded into the space thus released in McDonel Hall.

During 1966, discussions were taking place concerning the advisability of moving the Center into the Natural Science Building, which would place it physically in a building serving the College of Natural Science, and closer to the College of Education. During this time, Lyman Briggs College was also in the planning stages and the decision was made to house it in Holmes Hall. The early development of the Medical School preempted the space in the Natural Science Building and the Center activities in Holmes Hall were returned to McDonel Hall. The Director of the Center was appointed Dean of Lyman Briggs College and Dr. Julian R. Brandou was appointed Acting Director of the Center, and Director in 1967.

INSTITUTES

The expansion of the National Science Foundation program of support for science teacher institutes in 1956-1957 provided a mechanism for the SMTC to address one of its initial objectives, i.e., to provide opportunities for high school teachers to increase their subject matter competencies. The first summer institute for high school teachers was held in 1957 as a result of a proposal previously submitted from the Chemistry Department. Dr. D. A. Briesbach of Hiram College served as co-director. There followed a series of 52 high school teacher summer institutes in the various sciences and mathematics with NSF grants totaling $2,924,490 serving 2,293 participants through the summer of 1976. In the summer of 1958, an institute for Junior College Teachers of Physical Science was held and thereafter combined with those for high school teachers.

In 1958-1959, the first MSU Inservice Institute was operated for teachers of physical science and mathematics and repeated the following year. At this time it was discontinued because of the difficulty of identifying a sufficient number of teachers willing to take specific courses offered within a practical traveling distance of the Institute site. It was later reinstated for Mathematics teachers in 1966-1967 and by 1976, 12 institutes had been held serving 407 teachers.

Beginning 1960-1961, the first of a series of Academic Year Institutes for General Science Teachers in Junior High Schools was held. This program continued until 1969 for a total of 10 institutes serving 416 teachers. Support shifted from institutes to Cooperative School-College grants and College Teacher/Leadership Personnel Workshops during the early seventies and the overall support from NSF declined.

A large number of conferences and inservice workshops have been held during the past twenty years supported by industry, foundations, and in some cases, self-supporting through conference fees. These have addressed school administrators, science and mathematics supervisors, teachers, parent-teacher organizations, and others. They have served to alert those interested in newer developments in curricula, teaching techniques and content areas. Other conferences and workshops have been developed to inform and give teachers experience with new curricula as they have become available.

TRAVELING SCIENCE TEACHER PROGRAM

In the summers of 1956 and 1957, the SMTC Director had participated in the training and summary sessions for the Traveling Science Teachers program operated by the Oak Ridge Institute of Nuclear Studies under National Science Foundation grants. When it was learned that the NSF planned to expand the program to four Centers in 1959-1960, it was decided that the SMTC would submit a proposal to the National Science Foundation and a grant was made. Twenty experienced high school teachers were recruited and obtained a year's leave of absence from their schools. They spent three months on the campus constructing equipment, receiving background instruction, and preparing demonstration lectures. When schools opened in the Fall they loaded station wagons with their equipment and began visitation of various schools on invitation for a period of one week each in Michigan, Ohio, Indiana, Illinois, Iowa, Wisconsin, and Minnesota. By the end of the year they had visited 572 schools, served 2,125 teachers and spoken to 306,000 students. NSF reduced the program the following year to twelve traveling teachers but the summer training program served eleven teachers, in addition, who returned to their own schools at the end of the summer. The NSF then transferred the funds assigned to this program to other programs and the Traveling Science Teacher Program was discontinued.

HIGH SCHOOL HONORS SCIENCE PROGRAM

During the 1957-1958 school year, the Center Director assisted Mr. John Sebeson of East Lansing High School with plans for a greater Lansing area summer enrichment program in science for high school students, modestly subsidized by a local foundation. The program was held in the summer of 1958 at the East Lansing High School and a suggestion made that the SMTC prepare a proposal to the NSF for the following year. A grant was made and Dr. Isobel Blyth served as Director and Mr. Sebeson as co-director. NSF required solicitation of high quality applicants for participation from a wide area, with the result that relatively few local students were served by the program. The following year the local program was re-established at the high school and the NSF program has continued on campus to the present. From 1959-1976, seventeen sessions were held involving 1,327 high school juniors, approximately twenty percent of whom have appeared in the MSU freshmen classes a year later. The names of many former participants have appeared on the Honors College Roster and among the winners of Alumni Distinguished Scholarship, Rhodes Scholarship competition and similar competitions at MSU and elsewhere.

MASTER OF ARTS FOR TEACHERS DEGREE

As noted earlier, opportunities for post graduate instruction in professional education were available through summer and extension courses, but similar opportunities in specific disciplines were not.

Subject matter requirements, at that time, for teacher certification were often significantly less than those required for a regular undergraduate science major. It was difficult to complete a major in many disciplines and simultaneously include the 30 credits in professional education required for certification. The conventional entrance requirements for graduate work usually specified the equivalent of an undergraduate major. This situation required high school teachers, wishing to return to the university for graduate work, to complete a series of undergraduate courses prior to admission to graduate candidacy. A price that few high school teachers were in a position to pay. The traditional Science and Mathematics Departments were not inclined to alter, and in their view weaken, the accepted requirements for the Master of Science degree.

It was apparent that if high school teachers were to be given an opportunity to increase and keep current their subject matter competence and to qualify for advanced ratings, a separate post-baccalaureate degree at the Master's level, combining additional work in the disciplines with professional education, was required. Dean Muelder of the College of Science and Arts appointed the Director of the Science and Mathematics Teaching Center and Dr. Arnold Williams of the English Department to serve as a committee to develop a set of recommendations for the establishment of a Master of Arts for Teachers degree. Following a meeting between Dean Muelder, Dean Erickson, and the Committee, the necessary actions were taken and the degree program was approved by the Board on November 22, 1957. The degree was almost unique to Michigan State University, in that it was designed for certified inservice teachers and included a combination of work in the disciplines and in education.

The first two Master of Arts for Teachers degrees were awarded in the 1958-1959 school year. By the end of the 1975-1976 school year, 804 MAT's had been earned, 70% of these were in the sciences, 15% in mathematics, and 15% in other subjects. The large fraction in the sciences and mathematics was due to the financial support made available to inservice teachers by the National Science Foundation grants for inservice, summer and academic year institutes administered by the SMTC.

INSTRUCTIONAL ACTIVITIES

The original charge to the SMTC did not include responsibilities for the administration of instructional programs nor the teaching of regular courses, although the Center Director had continued to advise chemistry teaching majors and Center staff occasionally taught courses for other departments.

On July 1, 1962 the College of Science and Arts was divided into the Colleges of Arts and Letters, Social Science, and Natural Science. The previous Divisional Programs in Biological Science, Physical Science, and General Science were assigned to the Science and Mathematics Teaching Center which became the academic administrative unit for several hundred undergraduate and a few graduate students in the interdepartmental programs in Biological, Physical, and General Science in the new College of Natural Science.

Prior to 1964, introductory courses in Biology were offered by six Departments: Biochemistry, Botany and Plant Pathology, Entomology, Microbiology and Public Health, Physiology, and Zoology. These courses carried no prerequisites in Biology other than the University College Natural Science courses. There was a three term sequence in Botany, a two term sequence in Zoology, and one term sequences in the remainder. In addition, Biology majors were required to complete three term sequences in Chemistry, Physics, and Mathematics. This amounted to a minimum of 16 or more introductory, or freshman level, courses. The Director of the Science and Mathematics Teaching Center, in cooperation with the Assistant Dean John Zimmer, undertook an effort to have a single series of introductory courses in Biology developed which would serve as prerequisite to admission to more specialized courses in the various biological disciplines.

A two term sequence BS 211 and 212, dealing with many of the common elements from all introductory courses, was developed under the leadership of Dr. Fairley of the Biochemistry Department. The new course was first taught on a trial basis in the fall of 1964 and the second course in the winter of 1965. The live lectures were video-taped and the video-tape used for the lectures in succeeding terms during the year. New tapes were cut for each course at least once a year. Laboratories were provided in McDonel Hall and their equipment was partially subsidized by a National Science Foundation grant. In 1967 space for this program was provided in the Natural Science Building and the administration of the program was transferred to the Dean's Office of the College of Natural Science.

The initiation of the Academic Year Institute program required the development of new three term course sequences in Physical Science, Biological Science, Earth Science, and Mathematics. These courses were administered by the SMTC as a part of the Interdepartmental Program of the College of Natural Science and instruction was divided between SMTC staff and staff on loan from various departments in the College of Natural Science. Each of these series was designed to provide a solid base for further study in the discipline and pedagogy was treated separately in a special seminar and a demonstrations course.

A major revision of the curriculum for elementary teachers was made in 1961-1962. The new curriculum provided for three terms of Natural Science in the University College followed by one term courses in Mathematics, Physical Science, and Biological Science. The Physical Science and Biological Science courses were taught in the Center facilities and with Center staff. This function added several hundred student credit hours per year and required an expansion of the facilities and the staff of the Center.

Other institute programs, particularly the year long Experienced Teacher Fellowship project, EXTEF, sponsored by the USOE, contributed to new instructional developments. Sequences in reading and mathematics were developed in other departments and Center staff created courses in biological science, physical science, and earth science for this program. Demonstration teaching in nearby schools was also arranged for the EXTEF fellows. The emphasis for these 4th, 5th, and 6th grade teachers was on both the science content and the pedagogy of laboratory teaching in science and mathematics. New curriculum materials were thoroughly examined and the patterns of instruction appropriate to each were presented in special seminars. Many of the techniques and approaches developed in these programs were carried over to other inservice teacher workshops and class sessions.

THE DOCTORAL PROGRAM

The need for specialists in science education grew along with the rise in school enrollments following World War II and intensified after the resurgence of interest in the scientific manpower developments which followed Sputnik. The Center established in 1960 a cooperative relationship with the curriculum interest group in the College of Education to administer programs designed for students in science education. Faculty from the Center have served on doctoral committees in other parts of the College. Later, students completed their degrees under Elementary Education, Higher Education, Educational Psychology, and Secondary Education and Curriculum as additional faculty became affiliated with the Center and their interests broadened. In addition to students from the United States, international students from Australia, Israel, the Philippines, Vietnam, India, Venezuela, and Egypt, have completed their Ph.D. in the Center. In all, since the first doctorate in 1963, over seventy degrees have been earned.

The doctoral program provided significant contributions to the development of the Center by the involvement of talented young men and women in various SMTC teaching and research programs. Their own research investigations frequently stimulated a review of current practices and suggested new approaches and their participation in projects enhanced the quality of the program.

SCIENCE RESOURCE CENTER

Among the original functions assigned to the Center were several aimed at providing information and resources to inservice teachers and departments on the campus. Files were begun in the first office space which accumulated curriculum guides, catalogs, and reports of developments in science and science education for use by teachers. Subscriptions to the major periodicals in science and mathematics education were added regularly and selected items were bound for long term availability. The rapid development of nationally funded curriculum projects in the sixties produced a great deal of new material and increased the demand for dissemination of the new instructional techniques and ideas. By 1963, when the Center moved to McDonel Hall, the collection had grown to include reference works and textbooks in addition to samples of the new curriculum materials and expanding vertical files. The cataloging system, based on acquisition order, was replaced by a subject classification and the first shelf list was begun. The design of Holmes Hall permitted a full library, audio-visual facilities and a demonstration-laboratory with stockroom support. When the Science and Mathematics Teaching Center moved into Holmes Hall, the first full time staff was assigned to this operation. The laboratory room permitted instructional kits and apparatus to be acquired and used for teaching and inservice teacher support. When the Center was asked to return to McDonel Hall to make way for Lyman Briggs College, to house the Resources Center, two large classrooms in McDonel were completely renovated and a basement area was converted to a demonstration-laboratory. The Resource Center collection continued to grow to accommodate both preservice methods classes in science and mathematics and the programs for inservice teachers.

In 1968 the reference collection was again enlarged to include an emphasis on science education research and the ERIC materials. Some audio-tutorial and other media materials were also added, along with video taping and playback equipment. With the cooperation of other programs, a final cataloging of the entire collection was started in 1970. The Resource Center remains a distinct departmental-level service supported entirely within the Science and Mathematics Teaching Center and represents today a valuable and useful adjunct to science teacher education in the State.

TRIAL CENTERS

As a visible teaching center on the national level, SMTC had the opportunity to become involved in several of the larger curriculum development efforts. Materials tryouts were very important to the projects and usually involved teacher preparation, instructional support and a great deal of testing, observing and feedback to the originators. The Center worked with Biological Science Curriculum Study, History of Science Cases Instruction Project, Chemical Education Materials Study, Science Curriculum

Improvement Study, Intermediate Science Curriculum Study and hosted workshops or writing conferences for American Association for the Advancement of Science, Individualized Science Instructional System, Conceptually Oriented Program in Elementary Science, Physical Science Study Commission, and Modular Activities Program in Science. The largest of these projects was the SCIS Trial Center under Dr. Berkheimer, which involved teachers at all grade levels, K-6, in four (and later five) different school districts over the five year period, 1966-1971. Leadership Training workshops were later added to the program to help provide trained faculty at other institutions.

INDUSTRY COOPERATION

Cooperation with industry groups and associations and individual companies interested in aspects of science education improvement has remained a significant part of Center operations. One of the early projects was the introduction of the Bell Telephone "Aids to High School Science" kits to science teachers throughout the State. With the help of Mr. Stanley Puddiford, of the Michigan Bell Telephone Company, and the cooperation of the connecting companies, workshops were developed and conducted by Center staff each year as new kits were added to the program. The Center has held or participated in national reviews of learning aids produced by members of the Edison Electric Institute and offered the "This Atomic World" program to schools with the support of Consumers Power Company and the Detroit Edison Company. Both of these energy companies have also asked the Center to design and conduct teacher workshops, critique materials and to conduct studies of the effectiveness of certain projects. Union Carbide Corporation also requested help with a testing program of new classroom aids.

PROFESSIONAL ORGANIZATIONS

Center faculty and staff maintain active association with many professional organizations in science education and related areas. Service to these local, state, and national level groups has provided an important means of communicating with teachers and administrators. The organizations, in return, have recognized the leadership of the faculty by electing them to office and by inviting them to serve on major committees. Among those who held offices are the following:

National Association for Research on Science Teaching, NARST	President, Dr. Frederic B. Dutton and Dr. John M. Mason
	Secretary-Treasurer, Dr. T. Wayne Taylor
Michigan Science Teachers Association, MSTA	President, Dr. Julian R. Brandou and Dr. Frederic B. Dutton
	Secretary, Dr. Martin Hetherington
National Science Teachers Association (NSTA)	Board of Directors, Dr. Julian R. Brandou
Michigan Environmental Education Association (MEEA)	President, Dr. Martin Hetherington
Michigan Association of Science Education Specialists (MASES)	President, Dr. Julian R. Brandou
Central Association of Science and Mathematics Teachers (CASMT)	Board of Directors, Dr. T. Wayne Taylor
American Association for the Advancement of Science (AAAS)	Secretary and Chairman Section Q, Dr. Frederic B. Dutton

INTERNATIONAL

Science and science education are of international significance. Developing nations seek to expand their technological and economic bases creating the demands for assistance with curriculum developments, teacher education and inexpensive science equipment. The Science and Mathematics Teaching Center responded through regular NSF institutes and directly to requests. A major program with the Philippine American Education Foundation

(Fulbright) involved nearly all of the faculty over the period 1970-1976 and brought outstanding graduate students to the campus. Overseas teaching has also involved many faculty through University programs in Central America and Mexico, the Far East, Africa, the Middle East and in the United Kingdom. Dr. McLeod served a full year with the UNESCO project in Thailand.

ENVIRONMENT

National concern with the environment, and more recently with our energy resources, became an educational priority within the Center in early 1970. At that time, a survey of needs perceived by Michigan science teachers revealed considerable interest in approaches to environmental education. Dr. Martin Hetherington joined the Center staff that fall and conducted a national conference of educators, publishers and manufacturers on the problem. Since that time, he and others have been active in developing course work, conducting workshops and promoting the inclusion of environmental considerations in science education. The recent addition of the ENTROPY project to the Center operations continues this long term commitment.

A LOOK AHEAD

The future presents us all with uncertainties, the energy problem, the role of the University, the shifts in enrollment, the decrease in college age populations and our own changing needs. The Science and Mathematics Teaching Center has had a proud past, it has met the challenges facing science education with vigor and honesty. Our hope is that it may continue in the next decades to extend the resources of the Colleges it serves and the University to science teachers and students. For among all the doubts about tomorrow, there is one truth we can hold in confidence, "Science is the best way we've yet found to understand the physical universe, and man's ability to survive and prevail is dependent on that understanding".

CODICIL

This brief account of the formation and operation of the SMTC over its first twenty years is incomplete and probably not free of errors. Records are not complete, human memory is not infallible, and one's enthusiasm for specific interests may obscure one's vision of the contributions of others. It is hoped that errors of fact, omission, or commission, will be brought to the attention of the authors.

A CONDENSED CHRONOLOGY

SCIENCE AND MATHEMATICS TEACHING CENTER

1956-1957

A Science and Mathematics Teaching Center (SMTC) was proposed by L.L. Quill and F. B. Dutton of the Chemistry Department on April 6, 1956. On December 18, 1956 a recommendation was made by the Deans of the College of Science and Arts and Education and on December 28, 1956 the establishment of the Center was approved by the State Board of Agriculture effective April 1, 1957. Originally established in Room 200 Kedzie Chemical Laboratory with F. B. Dutton as Head and a secretary, the Center moved to new quarters in Room 403 in the University Library Building in June. Arrangements were completed for the first National Science Foundation (NSF) Summer Institute for High School Teachers, and proposals were prepared for future NSF programs. Assistance was given to the Lansing State Journal in planning for a Regional Science Fair in conjunction with their Annual Youth Talent Search and the National Science Fair. Working relationships were established with the departments in the Colleges of Science and Arts and of Education and with industries and professional organizations concerned with science and mathematics education. Efforts previously undertaken to establish the Master of Arts for Teachers (MAT) degree were continued. A brochure was produced describing the SMTC. Office services for a state mathematics competition sponsored by several universities and professional organizations were provided. Inquiries addressed to the "University" concerning science and mathematics education from teachers and students were processed or referred to other appropriate agencies.

1957-1958

Operated the first Michigan State University NSF Summer Institute for 50 High School Teachers of Physical Science. Initiated the collection of materials for the Instructional Materials Center. Participated in a discussion program on WKAR with Dean Melby. Three half-time assistants were provided by the College of Education. The MAT degree was approved by the Board of Trustees November 22, 1957. Moved to Room 513 in the College of Education Building upon its completion. Continued the activities previously initiated.*

1958-1959

Operated the second NSF Institute for 50 High School Teachers of Physical Science, a new program for 50 Junior College Teachers of Physical Science, and the first inservice program for High School Science and Mathematics Teachers. Served as Regional Director for the American Association for the Advancement of Science (AAAS) program for the use of special teachers in grades 4, 5, and 6 in Lansing schools. Developed the pilot program for Civil Defense Training Sessions and served as a depot for radiological monitoring equipment for this region. In cooperation with the College of Education operated a workshop for school administrators. Assisted in the introduction, use, and examinations for credit associated with the Continental Classroom television series. The first two Master of Arts for Teachers degrees were conferred.

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*The initiation of various new activities is noted each year. It may be assumed they are continuing and they will not reappear in the summary for succeeding years unless terminated or significantly altered.

1959-1960

Operated a combined NSF Summer Institute for 100 College and High School Teachers of Physical Science, the first High School Honors Science Program (HSHSP) for 100 high school juniors, the NSF Traveling Science Teacher (TST) Program with 20 traveling science teachers, and a second Inservice Institute (ISI) during the year in Physical Science and Mathematics. Established a Try-Out Center for the Biological Science Curriculum Study (BSCS) program. Operated a workshop for high school teachers on converting Bell Telephone Company salvage to useful science equipment. The SMTC offices and facilities were moved from 517 and 518 to 513 and 516 in the College of Education building. Dr. T. Wayne Taylor from the University of Texas joined the SMTC staff as Associate Professor and Mr. Jerrold W. Maben as coordinator for the TST Program. Professors C. L. Schloemer and George Fenn supervised the Summer Training Program.

1960-1961

Operated the first Academic Year Institute AYI with 49 participants and the first Michigan Academy of Science, Arts, and Letters (MASAL) NSF grant for a Visiting Scientist Program. Operated the final NSF TST program with 12 teachers supported throughout the year and 11 teachers trained during the summer but supported by local units. J. R. Brandou undertook the first consulting contract to provide services to 14 south Kent County schools. Hosted meeting of AYI Directors for the National Science Foundation. J.W. Maben assigned to Pontiac Schools as consultant for 18 months. Served as a Try-Out Center for the History of Science Cases Instruction Project developed at Harvard University.

1961-1962

Operated the first Summer Institute in Biology for 31 teachers, a new Summer Institute in Chemistry and Mathematics for 60 teachers, a first Summer Institute in Physics for 51 teachers. A MASAL grant provided consultation service to seven schools under contract. Center personnel cooperated with the CHEM Study program in the development of demonstrations. The Director served as coordinator of the Inter-School Committee. Staff developed prototype programs for the introduction of Bell Telephone Teaching Aids. The Center conducted a conference on-campus concerning science facilities for school programs K-12, in cooperation with the Scientific Apparatus Makers Association.

1962-1963

Operated the first three-year sequential Summer Institute for Biology Teachers with 60 participants. Approximately 20 at Gull Lake and 40 on-campus. Operated the first MSU CHEM Study Institute for 49 High School Teachers, and a Conference on Elementary Education with 16 participants. Sponsored Frontiers of Science Program for Michigan Chemical Industries. Provided pilot programs for the introduction of Bell Teaching Aids. Responsibility for the administration of the Biological and Physical Science Interdepartmental Programs of the College of Science and Arts were transferred to the Center when the College was divided into Colleges of Arts and Letters, College of Social Science and College of Natural Science. The reporting channel for the SMTC was transferred to the Dean of the new College of Natural Science. Served as host for a meeting of the Cooperative Committee of the American Association for the Advancement of Science and participated in the activities of the University Seven Point Committee, operated with support from the MSU Educational Development Program. Conducted a seminar on science education for the College of Natural Science.

1963-1964

The first NSF MASAL grant to operate the Michigan Junior Academy program was received. Moved from the College of Education building to McDonel Hall. Cooperated with Midwest Airborn Television in the preparation of a proposal. Courses in Science Methods for Teachers were transferred from College of Education to McDonel Hall to take advantage of the SMTC Instructional Materials Center and Laboratories. Plans completed for a new introductory biology sequence in the College of Natural Science. Participated in the development of plans for Holmes Hall academic areas which would house a portion of SMTC activities. Dr. Dutton began a year's leave of absence on June 1 to NSF and Dr. John M. Mason assumed the Acting Directorship of the Center.

1964-1965

Operated a Summer Institute in Animal Behavior for 40 high school teachers, and a Summer Institute in Physics for 40 high school teachers. Received an Equipment Grant from NSF to provide for television projection of microscopic material. The first class in BS 211 with 45 students in the Fall term and BS 212 with 31 students in the Winter term were taught under the direction of Dr. Fairley and Dr. Reed. Developed science teaching materials kits for use in the Elementary Intern Program (EIP) Centers. Cooperated with Channel 10 WKAR in their 4-H television series. Hosted AAAS Writing Conference for Science-A Process Approach during the summer session. Dr. Dutton returned on June 1 as Director of the Center.

1965-1966

Operated the final NSF Summer CHEM Study Institute for 44 high school teachers, and the final Summer Institute in Physics for 36 college teachers, a research study on Science Supervisors and Curriculum and a Conference of the State Supervisors of Mathematics for 60 participants. Dr. Mason undertook a study of the effectiveness of the BS 211-212 sequence. The Science and Mathematics Teaching Center program expanded into Holmes Hall with the administrative offices, the physical science instruction and the instructional Materials Center. The biological science instruction and related activities remained in McDonel Hall. Drs. Berkheimer and Hagerman were added to the staff of the Center and Dr. Reed was on leave. The Center was able to employ Gil Starks as the first full time person to service the enlarged Materials Center.

1966-1967

Operated the first Summer Institute in Numerical Analysis and computer programming and the first Experienced Teacher Fellowship program for 23 4th, 5th, and 6th grade teachers. Resumed the Inservice Institute Program with a new Institute for Mathematics teachers. Dr. Dutton was reassigned to Director of the Planning Committee for Residential College II and Dr. Brandou was named Acting Director effective December 19, 1966. The SCIS Try-Out Center operation began under Dr. Glenn Berkheimer. The Center moved from Holmes Hall to McDonel and the BS 211 and 212 program moved to the Natural Science building under the direct administration of the Dean's Office. A new MAT program in Planetarium Education was approved as part of the Physical Science Interdepartmental Program.

1967-1968

Operated a new Summer Institute in Calculus for 30 high school teachers, a new Summer Institute in Mathematics for 40 junior high school teachers, the first College Teacher's Workshop on the newer science curricula, and a one time conference for College Teachers on Elementary School Mathematics. Dr. Jean Enochs joined the staff replacing Dr. S. Arthur Reed in BS 202. Dr. Richard McLeod joined the staff to replace Dr. Brandou in the AYI program and the methods course. A major revision of BS 202 was begun with an Institutional Assistance Grant from USOE and funds from the MSU-EDP. Dr. Reed transferred to the BS 211 and 212 program.

1968-1969

Operated the final Experienced Teacher Fellowship Program for 15 elementary teachers, an Earth Science Institute for 40 high school teachers during the summer of 1968. During the academic year the first Cooperative Project was undertaken to expand the SCIS Trial Center and 40 new elementary teachers were trained in the program. A one time project for supervisors of MSU elementary interns was operated by Drs. Cheney and Brehm. The Center contributed staff time to two major planning efforts in the College of Education, the Trainers of Teacher Trainers (TTT) and Behavioral Sciences Teacher Education Project (BSTEP). Cooperative efforts with the Geology Department led to the approval of a new earth science teaching major in the Spring of 1969. Dr. Hagerman left the Center to join Lyman Briggs College and Dr. Richard Sauer joined the staff in biological science. Dr. Berkheimer traveled to El Salvador, Honduras, Guatemala, and Nicaragua to assist American Schools in those countries.

1969-1970

Operated the final Academic Year Institute for 30 participating junior high school teachers; over the past ten years this program served 416 general science teachers. Also conducted a new Cooperative School College Program in general science for 10 high school teachers and 60 students. The Center provided a massive inservice program for 180 teachers in the Carman School District, near Flint.

Dr. Taylor chaired the AAAS Committee which published the Guidelines for Content of Preservice Professional Education for Secondary School Science Teachers, Dr. Brandou edited a document for the Michigan Department of Education entitled Science Teaching with a Purpose. The Center received an unrestricted award of $3,000 from the Union Carbide Corporation. Mr. Larry Schmidt replaced Gil Starks as Instructional Materials Center Coordinator. Dr. Brandou completed a sabbatical leave between January and June, during which he conducted a series of drive-in conferences in Michigan, visited and taught in Japan and the Philippines. The fully revised BS 202 began operations as an audio-tutorial course Fall term 1969.

1970-1971

Operated the final Summer Institute in Earth Science for 50 secondary school teachers, the second program for 30 Planetarium Directors, a one time Summer Institute on the Impact of Science and Technology for 32 science and social science teachers. No college teacher workshops were operated during the Summer but an Innovations in Teacher Education Conference was held in the Fall, a Cooperative School College grant continued the Carman schools program through this year, and a one time Earth and Environmental Science Inservice Institute was conducted for 30 teachers. The Center co-sponsored with Consumers Power Company and the Detroit Edison Company the "This

Atomic World" program. Two lecturers, with a van of demonstration apparatus, visited nearly 300 schools in Michigan. A National Conference was held on Environmental Science Teaching Aids and a conference report published by Dr. Hetherington, who joined the staff this year, replacing Dr. Sauer. A second drive-in conference series was held in 11 Michigan cities and the Center sponsored the regional Tomorrow's Scientists and Engineers Competition. The first faculty, Drs. Taylor and Berkheimer, worked in the Philippines and the first doctoral students arrived at the Center under the Philippine-American Education Foundation (Fulbright) agreement. The Center continued the Michigan Junior Academy program on a self-supporting basis.

1971-1972

Operated the final Summer Institute in Calculus for 35 high school teachers, continued the High School Honors Science Program this year with 64 participants, began two new format College Teacher Workshops, one on the SCIS materials and the other on the Intermediate Science Curriculum Study for junior high schools (ISCS). The Detroit Edison Company discontinued "This Atomic World" in their area and Consumers Power completed their second and final year of this program. Detroit Edison supported the development of a new pilot workshop series in the Detroit area and Rand-McNally initiated a sponsored workshop series on SCIS. Dr. Cheney conducted a cooperative program on the Elementary Science Study (ESS) materials. A second unrestricted grant was received from the Union Carbide Corporation. The Center participated and supported initial efforts to try out Unified Science and Mathematics in the Elementary School (USMES) materials. The SMTC served as the regional center for the second and final regional competition for Tomorrow's Scientists and Engineers.

1972-1973

Operated the three year summer sequential Institute in Biology for a reduced number of participants (43) as the program begins to phase out, the HSHSP was again reduced from 64 to 52 students and several changes in the program were made. A new Science and Oral Language Curriculum Development project was begun to produce materials for bilingual students. The Center conducted Environmental Science Workshops, cooperated with 4-H to produce an Ecosystems Analysis activity and with Consumers Power Company introduced the Energy/Environment Game to over 350 teachers throughout Michigan. As a result of TTT involvement Dr. Haynes from the Physics Department and Dr. Timnick from Chemistry joined the group teaching science methods (ED 327S) and introduced seminars for preservice teachers, Drs. Enochs and McLeod cooperatively with the Department of Elementary Education faculty, conducted an experimental content/methods course. A new course for non-science majors, BS 200, was introduced and the revised PHS 203 was introduced in the Fall concluding the three year Institutional Assistance grant from USOE. Dr. T. Wayne Taylor, a faculty member of the Center since 1959, died in August 1972. A memorial library collection was erected in the Instructional Materials Center to house papers and books from his personal library donated by Mrs. Vi Marie Taylor. Mrs. Pauline McClure was added to the staff as coordinator of the Materials Center, a post filled the previous year by graduate assistants.

1973-1974

The final group of participants completed their third summer in the Sequential Biology program; during the 12 years of operation approximately 250 high school teachers studied on campus and at the Kellogg Biological

Station. The long running Summer Institutes in Mathematics for Junior High School Teachers and the Workshop for Leaders in Inservice Education, both directed by Dr. John Wagner, closed at the end of the Summer. The former, operating 7 years with about 270 participants and the latter for 6 years with 180. For the academic year, Dr. Cheney conducted a cooperative project on the AAAS Science-A Process Approach (SAPA) materials for 40 elementary teachers. A completely revamped general science major was approved by the Teacher Education Council and Dr. Brandou published a guide to the Metric Education literature and taught a summer seminar on the topic. Dr. Edward L. Smith joined the Center staff to strengthen the research program. He also developed a revised doctoral program with a more systematic research and evaluation base. Dr. Berkheimer and others published a new K-6 elementary science program.

1974-1975

The High School Honors Science Program now in its sixteenth year was again reduced to 40 participants. The Center provided consultant services to the Bay City schools during the year and conducted an NSF sponsored training session on Ideas and Investigations in Science (IIS) for 12 junior high school teachers. Dr. Cheney conducted two new COOP projects on the AAAS-SAPA materials, Dr. Stonehouse operated an inservice institute in Earth and Environmental Science and Dr. Wagner a Pilot Project in Mathematics. Dr. Hetherington was elected president of the Michigan Environmental Education Association and a new MAT in Environmental Science was approved for a two year trial period. Mrs. Bette Karmann replaced Mrs. McClure as Materials Center coordinator. Dr. McLeod was on leave to the UNESCO project in Thailand for the year.

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1975-1976

The Leadership Workshops, formerly College Teacher Workshops ended with the Summer period; during the five years, some 200 faculty were trained to implement ISCS and 160 for SCIS. The final COOP grant was received by Dr. Cheney for a SAPA program conducted during the academic year, the last ISI in Mathematics by Dr. Lauren Woodby was also operated, making ten years of such projects. The Center followed up on a Conference on Unified Science by Dr. McLeod to spend some time at the Ohio State project headquarters. Subsequently a Unified Science Curriculum Center was established in our Instructional Materials Center. To further emphasize the shift towards a research focus, a new library and study area was developed in the office wing and the Research Collection was removed from the Instructional Materials Center to this facility. Much of the premedical advising for undergraduates in Interdepartmental Biological Science was transferred to the Dean's Office.

1976-Present

The bicentennial year was greeted by a course brochure, in patriotic colors, covering the projected offerings of the Center for preservice and inservice teachers. Enrollment changes in elementary education prompted a major review of the enrollment projections for BS 202 and PHS 203. Dr. Brandou was appointed as the new Assistant Dean for Lifelong Education in the College of Natural Science and the search and selection process for a new Director culminated in the appointment of Dr. James Joseph Gallagher.

SCIENCE AND MATHEMATICS TEACHING CENTER

PERSONNEL ROSTER[*]

Anderson, James (1969-present)
Andrews, Edwin (1969-1971)

Baker, Bethel (1972-present)
Bauerle, Connie (1959-1960)
Berkheimer, Glenn (1964-present)
Blatt, Frank (1965-1966)
Blyth, Isobel M. (1960-1971)
Bowles, Joseph E. (1962-1963)
Boyll, June (1960-1964)
Braddock, James (1964-1965)
Brandou, Julian R. (1960-1976)
Brasseur, Nancy C. (1960-1961)
Brehm, Shirley (1962-present)
Britsch, Roberta (1974-1976)
Bucknell, Judith (1961-1964)
Byers, Joe (1973-1975)

Card, Dorit (1964-1967)
Chaffee, William B. (1963-1975)
Chamberlain, Von Del (1971-1974)
Cheney, Bruce (1969-present)
Cohen, David (1963-1964)
Cole, William (1973-present)
Collier, Calhoun (1967-present)
Collings, W. D. (1962-present)
Cowan, J. (1964-1965)

Devereaux, Ezra (1959-1960)
Dezeeuw, Donald J. (1962-1976)
Driesbach, D. A. (1957-1961)
Drew, William (1962-1975)
Dutton, Frederic B. (1956-1966)

Edwards, Thomas (1964-1965)
Elliott, Jane E. (Smith) (1960-1970)
Enochs, Jean (1967-present)

Fairley, James (1964-1966)
Fenn, Frances (1964-present)
Fitzgerald, William (1967-present)
French, Tena (1967-present)

Gallagher, James J. (1976-present)
George, Robert W. (1973-present)
Gingery, Laura (1967-1968)
Goodman, Harold (1959-1960)
Greeb, Faye K. (1967-1968)
Greenwood, Howard (1972-1973)

Hagerman, Howard H. (1966-present)
Hammer, Robert N. (1965-1967)
Hansen, Norma (1956-1958)
Hart, John (1976-present)
Haynes, S. K. (1958-present)
Hetherington, Martin (1970-present)
Heckrodt, Janet L. (1966-1967)
Henkel, Nancy L. (1960-1961)
Holmquist, Marjorie (1966-1967)
Hoopingarner, Roger (1969-1972)
Horvath, Barb (1972-1973)
Houston, William R. (1964-1971)
Hufford, Terry (1965-1966)

Jersey, Barbara (1964-1974)
Johnson, David I. (1973-present)
Jones, Carolyn (1968-1969)

Karmann, Mary E. (1975-present)
Kinsinger, Jack (1962-1963)

Lanier, Perry (1969-1975)
Lappan, Glenda (1967-present)
Liddle, Edward M. (1971-1972)

Maben, Jerrold W. (1958-1963)
Masla, John (1969-1970)

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[*] This list was compiled by reference to the annual University catalogs, directories and budget sheets. Full-time, part-time, and affiliated faculty and other staff have been listed. It will be appreciated if any errors of omission or commission are brought to the attention of Dr. J. R. Brandou, Assistant Dean for Lifelong Education, College of Natural Science, MSU or Dr. F. B. Dutton, 931 Wick Ct., East Lansing, Michigan 48823.

Mason, John M. (1960-1976)
Maxwell, Donald (1969-1970)
May, David (1972-1973)
McCarty, C. N. (1963-1965)
McClure, Pauline (1972-1973)
McDonald, Kenneth C. (1970-1971)
McLeod, Richard J (1967-present)
Merskin, Nancy (1958-1960)
Middleton, Janice (1961-1962)
Miller, Myron (1965-present)
Mitchell, Bruce (1973-present)
Montgomery, Norma (1967-1968)
Moursand, David (1966-1967)
Mouser, Gilbert (1971-1975)

Naegele, Carl J. (1975-present)
Neumeister, David (1970-1971)

Panush, Louis (1959-1961)
Pax, Ralph A. (1973-1975)
Peabody, Frank (1963-present)
Peebles, Charles R. (1972-present)
Porter, T. Wayne (1961-present)
Price, Ellen (1961-1966)

Rann, Sandra J. (1969-1970)
Rector, Suzanne K. (Seelman) (1967-1974)
Reed, S. Arthur (1963-1970)
Rine, Richard (1970-1973)
Ross, Lynn (1959-1961)
Ross, John (1971-1973)

Sauer, Richard (1968-1975)
Schloemer, C. L. (1960-1968)
Schmitz, Larry (1970-1971)
Schwarz, Giddeon (1970-1971)
Scrivens, Robert (1973-present)
Sebeson, John (1959-1960)
Shapiro, Lee (1974-present)
Sheridan, Mary (1963-1967)
Shulman, Lee S. (1974-present)
Smith, Carolyn (1965-1966)
Smith, Edward L. (1973-present)
Spees, Steven (1971-1975)
Spence, Robert (1965-1966)
Spurr, Selena (1976-present)
Starks, Gilbert (1965-1970)
Stehr, Frederick (1973-present)
Stokes, Lynne (1972-1973)
Stonehouse, Harold (1970-present)
Stovall, Barbara (1972-1973)
Sweetland, William (1973-1975)

Tanner, Glenda (1966-1967)
Taylor, Deborah (1967-1968)
Taylor, T. Wayne (1959-1972)
Timnick, Andrew (1970-present)

Vance, Irwin (1967-1969)
Victor, Robert C. (1973-present)
Vogel, Thomas A. (1971-1975)

Wagner, John (1962-present)
Walsh, William J. (1962-present)
Woodby, Lauren (1966-present)
Woody, Joyce (1959-1961)

Zimmerman, Annie M. (1968-1970)

SCIENCE AND MATHEMATICS TEACHING CENTER:
THE THIRD DECADE

James Joseph Gallagher
Michigan State University

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SCIENCE AND MATHEMATICS TEACHING CENTER: THE THIRD DECADE

Dr. James Joseph Gallagher, Director

Introduction

During most of its first two decades, the Science and Mathematics Teaching Center, (S.M.T.C.) faced the challenges of being in an ascending educational milieu. University enrollments and budgets were climbing. Elementary and secondary schools were constructing new buildings, enlarging their facilities, and improving programs and services. There was a pronounced shortage of science and mathematics teachers. New curricula were being developed as a result of massive infusion of federal and private funds into materials and media development. Extensive expansion occurred in all sections of education as the general public and our leaders anticipated that many old problems and those newly identified could be minimized, if not resolved, through education.

The staff and leaders of S.M.T.C. capitalized on this educational climate and acquired a national (and international) reputation for work in helping school personnel evaluate, adapt, and implement new curricula. This was consonant with their mission "to encourage and promote better science teaching in the State of Michigan."[1] As a result, the staff acquired unique skills for working with school personnel on instructional improvement. Also, the staff helped educate many of the leaders in science and mathematics education throughout Michigan and beyond. This represents an important accomplishment as well as an invaluable resource for any future work.

As part of a rapidly growing University, the leaders and staff of S.M.T.C. "facilitated joint action by the College of Natural Science and the College of Education for the preservice education of teachers."[2] This included a wide range of advisement responsibilities, as well as responsibilities for coordination of four interdepartmental programs in the College of Natural Science. S.M.T.C. also acquired teaching responsibilities including content courses in biology and physical science for prospective elementary teachers, methods of secondary science teaching, and a core program for the M.A.T. in Environmental Science.

The leadership role of the S.M.T.C. faculty was further enhanced by its involvement in numerous state and national professional societies in science and science education. Thus, as the S.M.T.C. begins its third decade, it has earned and enjoys a position of respect and leadership among the school people it was originally designed to serve, on campus for its multiple roles, and among professional peers across the nation and in many parts of the World.

A New Climate

The educational milieu of 1977 and that of the two decades past are quite different. Enrollments are declining at every level of education except in programs for early childhood and adult/continuing education. There is an oversupply of trained teachers. Many people, teachers and parents alike, are disenchanted with the new curricula that were developed during the past two decades and there is confusion over educational goals and objectives. The public and our leaders no longer view education as a potent force in solving societal problems. At least partially as a consequence, fiscal resources have not kept pace with inflation, although teachers and university faculty generally are paid better and enjoy a better standard of living than two decades ago.

New conditions prevail and with them new challenges. A selected set are outlined below:

1. The teacher population, at all levels, is more stable. Turnover of faculty members is low, and at the surface, that would seem to benefit quality instruction. However, older teachers tend not to return to the universities for additional graduate study. With the passage of time, their contact with universities becomes more remote and their knowledge tends to become increasingly obsolete.[3] Finding ways of helping all teachers continue their professional growth and development throughout their careers constitutes one of the great challenges of the coming decade.
2. According to nearly every measure available, high school graduates' achievement in mathematics, science, reading, and writing has declined during the last ten years.[4] The gravity of this decline may constitute a national crisis.

   The challenges of declining achievements are manifold. We need careful research to identify the nature, extent, causes, and possible "cures" of the decline. Initial evidence points toward a wide scale problem with causes that are deeply ingrained in the nature of our schools and reflective of contemporary society. One of our most important tasks is to identify and address factors which contribute to declining achievement over which teachers can exert some influence.

   Also, we must not cast blame. The problem is too complex and it is now affecting all levels of education, including teacher education. It is here that universities share in the problems, perhaps even become part of its cause.

3. Our society is facing new issues which will place new demands on science and mathematics education. Decreasing energy supplies, and their increasing costs, engender an array of new problems that will require changes in life style, behavior, and attitudes. Environmental issues are becoming increasingly complex and require more sophisticated educational treatments. Mathematics, science, and technology are continuing to escalate in importance in our culture and, yet, the general public appears to be more apathetic about their support and less informed about new developments. These issues and others that inevitably will emerge must be met by modifications in elementary, secondary, and university curricula.

Interest in the educational response to these societal issues has already begun to be formalized. The development of scientific literacy is a popular phrase, somewhat vaguely defined, that represents an important set of objectives of science education. Also, it has counterparts such as mathematical literacy, environmental literacy, and, in recent months, energy literacy. Although these terms may have highly personalized meanings, their general focus is that a "literate" citizenry would understand basic principles which are important in science, mathematics, environment, or energy, have some sense of the processes which gave rise to these principles, and be able to apply them in comprehending and resolving real problems of importance.

General statements, such as the foregoing, may characterize this important goal of education; but, to be useful, there is need for more explicit definitions. One task which lies ahead is to formulate definitions, which then can become new or expanded educational objectives for students in elementary and secondary schools. Statement of educational objectives for scientific, mathematical, environmental,and/or energy literacy will have implications for curriculum planning and development, preservice teacher education, inservice teacher education, and educational research. Inevitably, this effort will have a national scope and S.M.T.C. staff is already involved in shaping the new educational direction and will continue in the years to come.

4. Despite years of research on teaching in general, and in science and mathematics teaching in particular, classroom practice remains quite unaffected. Irrelevance of research to practice and inattention of researchers to the task of translating results into information and strategies useful to school people are central causes of this gulf. But now, both researchers and school people have begun to recognize the importance of each other's role improving teaching and learning. Thus, a new climate for research exists that will foster new alliances, engender new questions, and yield new types of research.

With its history of involvement with schools, S.M.T.C. is in an enviable position for conducting research which addresses important problems. As our new model for service is implemented, the two-way flow of information between schools and universities will be enhanced. This should further improve our ability to conduct research on important questions concerning practice and provide school people with research results in a form that can be used in resolving real problems.

5. The number of traditional college age students is declining and higher education must make adjustments. The most predictable of these is that universities will attempt to attract new audiences, including older students, and a wider range of eighteen to twenty-two year olds. Providing educational programs for these groups will present us with different and new challenges which will test our ability to organize information more efficiently and teach it more effectively. As university faculties attempt to teach these "new students" the need for careful analysis of knowledge for more effective teaching, as well as research on teaching-learning processes will become evident. The current and past work of the S.M.T.C. staff in teaching basic science to prospective elementary teachers will provide invaluable experience in helping us meet the challenges of these two new university populations.

Future Roles of S.M.T.C.

The S.M.T.C. will continue to be a responsive group operating from a unique vantage point between two colleges. Its activity over the next decade will be in four major areas:

1. Service to the University and its Students

   S.M.T.C. will continue to provide service to the University and its students in a variety of ways including

   (a) teaching courses in science and science education;

   (b) administering intercollegial and interdepartmental programs;

   (c) advising students; and

(d) providing liaison between the College of Natural Science and the College of Education as well as across the University in matters concerning the education of teachers regarding science, mathematics, environmental education, energy education, and other science/technology-based issues.

Although the need for large numbers of new teachers is declining, a continuing supply is necessary. One of our major objectives in teacher education will be to improve the quality of the courses we offer for prospective and practicing teachers. Our initial focus will be in the two science content courses for prospective elementary teachers, because the students who take these courses represent an important and challenging audience. Moreover, these students typify the broader range of eighteen to twenty-two year olds which universities inevitably will be serving, and our work in addressing their instructional needs may have wide applicability. Jean Enochs' paper details several of the proposed activities relating to one of these courses.

Intercollegial and interdepartmental programs are continuing to grow in importance as students and faculty become more aware of the soundness of a broad, interdisciplinary educational program as preparation for life, further study, and the world of work in the decades ahead. Thus we will continue our efforts in support of these programs and strive toward their continual improvement.

Student advisement may be one of the most important determiners of quality education, especially at a large institution like M.S.U. where the variety of available courses is so wide. We will continue to work with our own staff and the many advisers from other departments to maintain excellent advisement.

In the decade ahead it is predictable that energy education will become a new locus of interdisciplinary activity. It will involve departments in our two parent colleges and in several others including Social Sciences, Engineering, Agriculture, and Urban Development. We have already established a national leadership role in energy education and will continue to assume a leadership position in it, as well as in other interdisciplinary areas which will emerge and which lie in our domain of science, mathematics, and environmental education. Our position as a Center, with ties between the College of Education and the College of Natural Science, both supports and demands this response. Martin Hetherington's paper outlines our efforts to date in energy education and projects future work.

II. Research and Development on Curriculum, Learning, and Instruction

In recent years there has been an increasing emphasis on research in S.M.T.C. Excellent ground work has been done and increasing evidence of our commitment and contributions to research is available.

The S.M.T.C. staff and numerous others in the College of Education, the Institute for Research in Teaching, and the College of Natural Science have strong interest in research on teaching-learning processes, teacher education, and curriculum development. The establishment of the Institute for Research in Teaching has given a sharper focus to these research efforts for members of the S.M.T.C. staff. We are developing plans and seeking financial support for a small number of significant studies on cruical issues including processes teachers use in planning instruction, teaching-learning processes, underachieving high school students, and models for assessing the impact of service programs. Papers by Carl Naegele and Edward Smith detail our projected efforts more fully.

During the years ahead we plan to increase our research efforts through acquisition of external funding and through management and coordination of our resources in instruction, service, and research. Enhancing complementarity of these activities can result in improved output from all three.

III. Service to the Schools of Michigan

S.M.T.C. will continue to provide service to the schools of Michigan. The staff has already begun to investigate and develop new, more cost-effective ways of assisting schools with instructional and curricular improvement, planned change, and inservice education of teachers and other staff members. We are exploring new models of service which

a. address current needs as perceived by school personnel;

b. provide systematic continuing support for teachers rather than random input;

c. utilize our resources in coordination with those from other units in the University;

d. capitalize on the skilled leadership in the schools as both linking agents and resource persons;

e. are both cost-effective and can be maintained given current constraints on school and university budgets;

f. aid in identifying new informational needs that can be met through research and application of existing knowledge;

g. communicate the results of research in a form that is useful to practitioners; and

h. have wide applicability in providing continued professional growth for school people and as such can be adapted by the College of Education and other institutions.

A major segment of this effort is dealt with in detail in Richard McLeod's paper. Our Resource Library of Instructional Materials is another service-related activity. Also, plans are being developed to find new ways of providing teachers with information on developments in science and mathematics as well as information concerning science/technology-based social issues such as energy and environmental topics.

About twenty percent of our effort is now devoted to service to schools. It is hoped that the total effort for service will increase through external funding.

The S.M.T.C. staff will continue to keep abreast of curriculum developments, work with school curriculum committees to help them make appropriate selections of instructional materials, and work with teachers and students in the classroom. This level of involvement is essential not only as service to teachers and schools, but also to maintain the authenticity of the staff. This intimate involvement with the problems of the schools will enable the staff to develop more formal products that are viewed by practitioners as authentic.

IV. Service to Professional Organizations

Service to professional organizations is an important mechanism for improving the quality of instruction in the schools of Michigan as well as nationally and internationally. Our involvement with professional organizations provides us with opportunities to work broadly with others in identifying and clarifying needs and in developing and implementing solutions. It also provides opportunities for contacts that result in improved capability to attract funding for our projects as well as to identify people who can assist us with or serve as clients for our programs. Our work in service to professional organizations will be carefully selected to maximize our impact in improving science and mathematics education as well as in areas such as environment and energy. Our work will continue at state, national, and international levels at about ten percent of faculty effort.

In conclusion, S.M.T.C. will continue to act as it has in the past, as an agency within the university which has an instructional and research thrust like other departments, but which has other goals including a coordinating function within the University, an unique service function to the schools of Michigan, and a mission of service to professional organizations as an additional vehicle for improving instruction in the schools. The staff is committed to retaining and enhancing the preeminence of the S.M.T.C. within the university, with the teachers and leaders of the schools of Michigan, and with professional peers across the nation and beyond. It is hoped that in the decade ahead, we will be able to attract additional resources and use existing ones more effectively so that we may

1. expand our research efforts;
2. develop and implement improved models of service to schools;
3. increase our involvement in mathematics education;

4. continue to be responsive to the needs of personnel in the schools of Michigan;
5. continue to be responsive to societal issues, such as energy, environment, and student achievement, as they emerge;
6. increase the effectiveness of our instructional offerings;
7. expand our Resource Library so that we can serve a wider audience; and
8. continue to offer leadership in identifying and articulating areas needing attention including curriculum, instruction, and research.

In the past, S.M.T.C. has operated in roles consonat with the aims of Michigan State University -- blending teaching, scholarly research, and service to the people of the State. During the decade ahead, we will continue to serve these roles but in the context of the new issues which become important. We will provide needed leadership in helping to identify, articulate, and resolve these issues, capitalizing on our unique capabilities in merging theoretical knowledge and practical wisdom.

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1. Dutton, Frederic B. and Julian R. Brandou. "S.M.T.C.: A Retrospect." Paper presented at S.M.T.C. Conference, May 17, 1977.

2. Ibid.

3. McLeod, Richard J. "New Models for Inservice Education for Teachers: A New Appraoch to University Service to Schools." A paper presented at the S.M.T.C. Conference, May 17, 1977.

4. Gallagher, James J. and Glenn D. Berkheimer, "Research Evaluation and Identification on The Underpreparedness of High School Graduates." Proposal submitted to National Science Foundation, April 1977.

Developing Scientific and Mathematical Literacy Among Elementary and Secondary School Students

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Michigan Technological University

Developing Scientific and Mathematical Literacy Among Elementary and Secondary School Students

Dr. Michael L. Agin

The purpose of this paper is to discuss the development of scientific and mathematical literacy of students in elementary and secondary schools. In order to do this it will be necessary to establish a philosophical base upon which to build. This will require the defining of science and mathematics, discussing the purposes of scientific and mathematics education, as well as the defining of scientific and mathematical literacy.

Once this philosophical base is established, there will be a consideration of several aspects associated with the development of literacy: K-12 curriculum, the learner and instruction, some problems, and considerations.

What Science and Mathematics May Be

In a culture with differing points of view there are a number of ways in which science and mathematics can be defined. The purpose of this paper is not to consider "what science and mathematics are" but to present a central position and describe "what science and mathematics may be."

Using a composite of Barber and Lachman, science may be considered to be:

1. an organized social activity; (1)
2. knowledge-generating;
3. continuous, creative, and cumulative; and
4. composed of
   a. acquired facts,
   b. fundamental objectives,
   c. basic assumptions,
   d. operating conceptions, and
   e. general methodologies. (2)

Science includes the biological, physical, earth, and social sciences and other activities of our culture which are conducted by people and follow rational guidelines in the study of physical, biological, and social surroundings. The methods science uses are most often empirical, and include inductive and/or deductive reasoning.

Mathematics may be considered to be:

1. a way of thinking;
2. a language;
3. an organized structure of knowledge;
4. the study of patterns; and
5. an art.

Mathematics is more than arithmetic, algebra, geometry, statistics, etc.; it is a creation of the human mind and is based upon a logical scheme of deductive reasoning that is required for the ultimate acceptance of generalizations. (3)

Science and mathematics are activities taking place in a social-cultural milieu--activities which generate knowledge. They are man-made, possess operating procedures, basic assumptions, and are used by people to describe, understand, and explain their surroundings.

Purposes of Science and Mathematics Education

What does this mean for the education of children, especially in grades K-12? To answer this it is necessary to consider the purposes of science and mathematics education.

Analysis of policy statements in the literature of science and mathematics education leads to the conclusion that science and mathematics have three basic purposes. Expanding the statement of Pella, et al (4) to include mathematics, then the purposes of science and mathematics are to:

1. prepare scholars in the discipline;
2. provide individuals with a background in science and mathematics for technological or professional occupations; and
3. provide individuals with a background in science and mathematics as a part of their general education for effective citizenship.

The first group includes those individuals who follow their intellectual interests and aptitudes to pursue scientific and mathematical knowledge to its very frontiers. It includes research investigators and academicians in the various abstract and theoretical fields of science and/or mathematics. These individuals are often called "pure scientists" or "pure mathematicians"--mythical but popular phrases.

Included in the second group--usually called "applied scientists or mathematicians"--are individuals who work in technology-, science-, and mathematics-related occupations or professions. These"applied scientists and mathematicians"--doctors, nurses, engineers, economists, sociologists, and so on--usually possess motivations and pursue goals that differ from those of the first group. Science and mathematics used by the "applied" group are focused more toward practical than theoretical problems.

The third group, the bulk of our population, includes many political, industrial, business leaders--in positions to influence decisions made by government at both the state and federal level--or ordinary hard-working citizens. Many in this group are unaware of the influence that science and technology have on their lives. Although they live in a scientifically- and technologically-oriented culture, these individuals often have extremely limited backgrounds in science and mathematics. In addition, they have little or no motivation to learn more about these areas.

The greatest emphasis in education should be on this segment of the population. The effectiveness of these people as citizens and leaders should be a principal goal of education. Science and mathematics education can help the development of more effective citizens by

1. helping individuals recognize their need for a better understanding--working knowledge--of science, engineering, and technology; and
2. motivating them to satisfy their needs for a better understanding.

When should this begin? As early as possible. Parents, relatives, etc., should start and maintain children on a lifetime of curiosity and openmindedness. In the context of formal education the efforts of parents and others should be complemented and expanded. This is where general education begins. It is from these modest beginnings that scientists, mathematicians, and effective citizens arise.

Literacy in Science and Mathematics

The goals of science and mathematics education in the framework of general education have been given many names and described in many ways throughout the history of education in the United States. At present the most popular terms being used are "scientific literacy" and "mathematical literacy." It will not be necessary to spend time going into their history but an attempt will be made to establish a framework for these two terms from which to consider the question of development.

What is "scientific literacy"? Better yet, who is "scientifically literate"? Although there are several excellent descriptions of this term--NSTA, 1964 (5); Pella, Gale, and O'Hearn, 1966 (6); and NSTA, 1971 (7)--the description of Hurd and Gallagher has been selected because it implies growth rather than a finished product. They visualize individuals using their formal science education--including conceptual knowledge and methodologies--as a foundation for further growth and present a dynamic rather than static view of science education.

According to Hurd and Gallagher, the scientifically literate person will increasingly:

A. Appreciate the socio-historical development of science.
   1. Realize that modern science is a recent development.
   2. Be aware that human thought has changed radically since medieval times.
   3. Appreciate that modern science is cumulative and self-accelerating.
B. Become aware of the ethos of modern science.
   1. Appreciate the significance of the view that science is universal.
   2. Appreciate that ideas are continually subject to validation by test.
   3. Appreciate the communality of scientific knowledge.
   4. Understand the scientists seek understanding of the universe and the betterment of man's estate.
   5. Appreciate the scientists' attitude of skepticism.
C. Understand and appreciate the social and cultural relationships of science.
   1. Understand the social influences of science.
   2. Understand that science is not isolated from but is to a large degree a product of the culture in which it exists.
   3. Understand the influences of modern science on society.
   4. Understand the impact of science and technology on modern society, and its attendant problems.

D. Recognize the social responsibility of science.
   1. Strive to close the gap between public knowledge and the frontiers of inquiry.
   2. Help in the enlistment of adequate scientific manpower through concern for education.
   3. Offer rational options when making social and moral decisions.
   4. Appreciate that proper application of discovery is the domain of the society-at-large.
   5. Understand that it is the responsibility of the scientist to be able to interpret the consequences of his work for man's common-sense view of the world. (8)

Who is "mathematically literate"? Applying the growth concept to Johnson and Rising's description of the mathematical needs of youth provides us with an excellent answer.

The mathematically literate person will increasingly:
   A. ...Know how mathematics contributes to his understanding of natural phenomena.
   B. ...Understand how he can use mathematical methods to investigate, interpret, and make decisions in human affairs.
   C. ...Understand how mathematics, as a science and as an art, contributes to our cultural heritage.
   D. ...Prepare for vocations in which he utilizes mathematics as a producer and consumer of products, services, and art.
   E. ...Learn to communicate mathematical ideas correctly and clearly to others. (9)

Assuming that these statements are adequate--that individuals become increasingly aware and appreciative of the various aspects of science and mathematics--then the efforts of science and mathematics education (k-12) should not be directed toward a finished product but to providing individuals with a foundation for additional intellectual growth. At each level of intellectual development children should be building toward greater scientific and mathematical maturity. This growth toward greater scientific and mathematically mature individuals is the philosophical base of this paper.

Developing Literacy

How should science and mathematics education be organized to foster the development of scientifically and mathematically literate individuals? Most educators agree that the most ideal science and/or mathematics program is the K-12 integrated instructional sequence. Developers of a K-12 program can include in their planning the integration of various concepts and can provide for a continuity of concept presentation that is difficult to achieve in other developmental formats in which different levels of planning are done by different people who may not be able to communicate with each other.

In developing these programs it is imperative to keep in mind the learner, his intellectual development and potential. It has been stated that concepts can be taught by indoctrination, induction, deduction, extrapolation, interpolation, analysis, synthesis, and problem solving. (10) However, this does not mean that children at all ages can be taught all concepts by all the previously mentioned processes, but it does pose the question: "When can certain concepts and their modes of formulation be introduced in the learning process?"

There are two viewpoints that merit attention. The first point of view concerns itself with the developmental aspects of learners as it relates to the development of the potential of the human mind. According to Piagetians, cognitive development occurs in stages and the learning process is governed by the development of the individual. This school of thought maintains that the nervous system matures over time and reaches a point of sophistication where it can go beyond the need for physical stimuli in order to cope with abstractions. As the mind matures mentally it becomes less and less dependent upon physical objects for its source of information and operation. But before this time, the learner must have experiences that have associated with them some form of physical representation. (11)

The other point of view is not specifically concerned with the genetic developmental considerations of learning. Gagne', a spokesman for this view, contends that readiness is essentially a function of the presence or absence of prerequisites. The individual passes toward higher levels of intellectual operations by experiencing and mastering lower levels of learning first. (12) In regard to this point, Gagne' states:

> Knowledge is a hierarchy of ideas in which the more complex ones depend for their acquisition on the previous mastery of simpler ones. Thus, when a curriculum designer has in mind a set of ideas he wants students to acquire, he must ask himself very systematically, "What must the student already know how to do, in order that he can acquire this new knowledge?" ...Unless a student can progress regularly from one idea to the next, we lose him. (13)

Although it appears that these two views are contradictory, they are complementary. Piaget infers that concept learning occurs only when the mind has developed to the proper level of cognition. He does not state how or how much learning can occur, but when it can occur. Gagne', on the other hand, is primarily concerned with the prerequisites of the learner and the sequencing of instruction.

It is necessary to provide science and mathematics instruction that will permit the individuals to interact with stimuli of concepts that are consistent with their level of maturation, their natural ability to learn, and their previous experiences. What a child is expected to learn must be put in a form that will be meaningful. Piaget's developmental model is education's best guide, to date, for the overall development of K-12 science and mathematics programs. The view held by Gagne' and others is probably most useful at the various levels of instruction where most science and mathematics curricula are organized in some form of hierarchical structure.

Ausubel integrates these ideas when he states:

> The intellectual development of children can only be accelerated within the limits imposed by the prevailing stage of the intellectual development. These limitations cannot be transcended through experience. One can, at best, take advantage of methods that are most appropriate and effective for exploiting the existing degree of readiness. (14)

In order to understand science and mathematics, students must be exposed to the concepts and methods of these disciplines. There should be a continual development of the individual's competence in the application of scientific methodologies, mathematical techniques, and in the formulation of concepts. This can be achieved most effectively by well-structured, activity-oriented instructional situations that provide the learner firsthand experiences with familiar objects. The guidelines for these activities should direct the students through processes that are meaningful quests for concepts.

In science education (K-12) there is a need to restructure the teaching of science and to cut across the many barriers that separate the sciences from themselves and the humanities. Compartmentalized knowledge should be integrated into new concepts and conceptual schemes. This does not mean the abandonment of the teaching of concepts and methodologies presently in use but the reorganization and integration of many of them with those of other disciplines--social sciences, humanities, mathematics, etc. As Hurd states:

> A general education in the sciences should make it possible for people to appreciate the worthiness of the scientific enterprise and to [illegible] its achievements....This means that the present science curriculum will need to be changed to provide a wider picture of science....It will require reordering the subject matter of science, placing it in a cultural context and demonstrating more concern for human betterment. (15)

There are many simple concepts, especially in the earth and biological sciences, that can be taught to children in grades K-3. These students, however, should be encouraged to participate in meaingful experiences with familiar objects which they can observe, manipulate, compare, classify, and describe. Later in this learning sequence the student could be asked to measure, order, raise questions, and make predictions about objects. (16) The rote memorization of meaningless techniques, facts, etc. should be discouraged. Each experience should be a continuation of previous activities and the foundation for future ones; these experiences must have meaning to be useful to the student at some later date.

In grades 4-6 students should be encouraged to work more independently and at higher levels of sophistication. They should continue to participate in previous activities and at the same time expand their repertory of experiences to include more quantitative observations, measurements, ordering, and predictions through inferences derived from observations. (17) The concepts used at this level should be an extension of those used at the K-3 level but should be more abstract and generalized.

It would be ideal to see all students so interested and enthusiastic about science that they would take science in all grades K-12. But this is still an unrealized goal. Since many students do terminate their formal science education in grades 7-9 it is important that a concerted effort be made to introduce them to the study of the social interactions of science.

It is important that students be given the opportunity to begin to grow in their knowledge of science and its social implications. At this level students should also be encouraged to study their biological and physical environments in greater depth. They should work with processes at levels more sophisticated than those used in K-6.

The students should:

a. experiment with and identify relevant variables;

b. maintain accurate records of procedures and results;

c. measure with direct and indirect methods;

d. identify, modify, and extend inferences;

e. modify and extend physical and mental models to include new observations;

f. make inferences from graphs and tables; and

g. report experimental results. (18)

The ideal program in grades 10-12 would be an integrated science program where students could study and become involved in activities pertinent to all sciences. But this is a dream for the future. Although some schools do have integrated science programs most schools and teachers are not prepared to attempt this task. At this level of secondary school, however, the several course options offered should include:

a. identifying and correlating data;

b. experimenting with natural phenomena;

c. recognizing experimental errors and limitations;

d. recognizing limitations of models;

e. selecting acceptable interpretations; and

f. formulating operational definitions--mathematical and non-mathematical. (19)

The physical, biological, earth, and the social sciences should consider what influence the earth and its surface features have on the development of living organisms, especially human beings, and the changes to the earth these organisms have caused. Pollution, overpopulation, resource depletion, etc., are problems associated with all sciences. We should start studying our natural and social world as an integrated whole and stop dissecting and categorizing it. There are many problems these students can study that will not be solved by any one science; their solutions will require the cooperation of all the sciences--natural and social--and by literate citizens.

Several topics that could be used for teaching science and its social implication are:

1. Nuclear Energy and Its Social Implications;
2. Pesticides and the Silent Spring;
3. Technological Developments and Social Implications Associated with Navigation, Military Weapons, and Mining; and
4. Eugenics - Moral, Amoral, or Immoral. (20)

I will not spend as much time discussing the mathematics program (K-12) as I did the science program for two reasons. First, I do not claim to be an expert in this area. I have learned much about mathematics since I have been working with mathematics teachers, and enjoy studying its many manifestations. But my claim to fame in the field of mathematics is limited to the winning of a solid chocolate rabbit in an arithmetic contest in the third grade (circa 1943).

Secondly, I feel that mathematics educators have been able to put together some of the best integrated scope and sequence designs of all the academic disciplines. Mathematics educators have not been able to settle all the issues of appropriate sequencing but they do exhibit a fair amount of agreement. Several discussions, however, have centered around:

1. what should be taught in grades 7-9,
2. how much and in what way should mathematics be applied to other disciplines, and
3. how much emphasis should be placed on abstractions, rigorous proofs, and deduction. (21)

Mathematics education should broaden its scope and be more imaginative if it is to provide individuals the foundation and experiences for growth. As in the case of science education, there is a need to develop competencies in the basic skills, techniques, vocabulary, concepts, and logical procedures of all students. In addition, mathematics education should be extended to learning situations where it helps individuals to see how mathematical procedures can be used to evaluate questions. In other words, mathematics should attempt to fit into the broader goals of education. As Kline states:

> Knowledge is a whole and mathematics is part of that whole. The subject did not develop apart from other activities and interests. To teach mathematics as a separate discipline is a perversion, a corruption and a distortion of true knowledge. If we are compelled for practical reasons to separate learning into mathematics, science, history and other subjects, let us at least recognize that this separation is artificial and false. Each subject is an approach to knowledge and any mixing or overlap where convenient and pedagogically useful, is desirable and to be welcomed.

and further:

> What we should be fashioning and teaching, then, beyond mathematics proper, are the relationships of mathematics to other human interests--in other words, a broad cultural mathematics curriculum which achieves an intimate communion with the main currents of thought and our cultural heritage. Some of these relationships can serve as motivations; others would be applications; and still others would supply interesting reading and discussion material that would vary and enliven the content of our mathematics courses. (22)

It has been said that science and mathematics instruction should be integrated. In fact, many of the activities of science may appropriately be considered mathematically-oriented. As Gagne' states:

> The hierarchy of capabilities that is learned when an individual studies science has several things in common with that of mathematics. There appear to be two primary reasons for this. First, is the fact that both subjects must start with a consideration of concrete objects in order that the earliest forms of learning will be made possible. And second, the student of science very early begins to use the concepts and principles of mathematics, as for example in counting and measuring natural phenomena, or in dealing with proportions and directions and sizes. (23)

But at higher levels, science and mathematics tend to branch in such a way that their integration becomes more difficult. In fact, at higher levels of abstraction science needs and uses mathematics but the reverse is not necessarily true--developments in mathematics often enhance developments in science.

The integration of science and mathematics in an interesting idea that will have to evolve over a period of time. It will require new philosophical thinking of science and mathematics education. Teacher training requirements will have to change. This integration will alter the basic system of instruction. The Minnesota Mathematics and Science Teaching Project (MINNEMST) was one of several programs designed to integrate science and mathematics. But the project has been terminated and it is difficult to assess its effectiveness or to infer the feasibility of the integrated science/mathematics approach. (24)

This discussion brings us to the question: "Where should the K-12 science and mathematics programs be developed?"

Most educators agree that science and mathematics programs should be developed locally. Each community or school system attempting to develop a program is somewhat unique in a number of characteristics; therefore, there is no formula that works for all schools. What works for one school district may not work for another. The NSTA Committee on Curriculum Studies K-12 states:

> Although the development of scientifically literate individuals is considered to be the central purpose of science education, a single or "best way" of pursuing this goal cannot be specified. The diverse nature of schools, students, and teachers necessitates a variety of programs and approaches. (25)

In The Continuing Revolution in Mathematics, D. K. Richards concludes:

> The role of each school or local district seems clear: to examine critically the approaches suggested by various study groups, commercial companies, and other local units, to make use of those elements (of curriculum) that satisfy its own particular requirements. Local units cannot abdicate their responsibility for curriculum development by waiting

> for others to do the job for them. Commercial textbooks are not the answer. They, along with state curriculum guides, can only assist....the State will provide a broad curriculum framework...Local units can design their own curriculum within this framework. (26)

This does not mean that local school districts should isolate themselves from the educational community-at-large. They should remain in contact with educational groups at all levels. Federal, state, and private educational agencies also have a role in curriculum development, mostly advisory but nevertheless important. These agencies can assist local school districts by providing them with a general picture of science and mathematics education. Local districts should be the final arbiters on matters of curriculum development and implementation but these various national, state, etc., agencies could provide:

1. guidelines for developing, implementing, and evaluating curriculum programs;
2. reviews and intepretations of research pertinent to curriculum development;
3. the services of consultants;
4. summaries of curriculum development efforts of other districts;
5. in-service programs for faculty development; and
6. a general intellectual-professional climate for curriculum development.

Problem Areas

There are a few points I would like to present in regard to the implementation of science and mathematics education. The implementation of these programs toward scientific and mathematical literacy and their evaulation face difficult times because of several problems.

1. There is a proliferation of jargon--different labels for the same thing. Science and mathematics educators use labels that do not tell anyone anything and have frightened many prospective buyers from the market place. For example:

   a. Interdisciplinary, multidisciplinary, and transdisciplinary are used to describe the teaching of two or more disciplines simultaneously.

   b. Instruction, inquiry, and teaching for discovery are used to describe almost every type of classroom situation imaginable.

   c. Finally, there are behavioral, performance, and instructional objectives and, in addition, educational specifications.

There are times when the use of colloquial terms is necessary but there is also a need to have an exact language that is standardized and understood by all.

2. There is an attempt to follow "theories of instruction" when in reality there are many descriptions, very few correlations, and no reliable explanations (i.e., theories). Much more investigative research is necessary before correlative concepts of educational practices will enable educators to make predictions. At present, we cannot predict how the use of a certain teaching methodology will influence an individual or

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group of individuals. Until we can present "if-then" statements about teaching methods, learning situations, etc., we will be restricted to describing what has been done and not why or how something in education will occur.

3. Science and mathematics is being taught outside of any cultural or social context. Some nationally developed programs have tried to teach subject matter without any concern for how these things came about--in a "social vacuum". How long did it take an Einstein or a Rutherford to achieve their results (in one chapter of a text or in four laboratory activities)? We are teaching ex post facto--descriptions and explanations of discoveries that are different from reality. We are looking at events through their results rather than looking at some events to make their results more understandable. Where does serendipity fit in our scientific and mathematical heritage?

4. There is a campaign to make curricula "teacher proof". Everything is planned to the last detail. Some teacher education institutions try to make robots or technicians out of their prospective teachers. They teach them one or no approaches and very little understanding of science (or mathematics) and then tell them they are "prepared". Teachers are human beings, not computers that have to be programmed--humanism in education begins at the teacher education institution.

Let's prepare the prospective teachers in subject matter, professional education, and general education and let them decide whether they want to use individualized or group instruction. Select individuals who like to work with young people, give them good academic, professional, and general education experiences and they will develop good programs.

5. We are being "brainwashed" by advocates of an extreme view of "Existentialism" who do not (or really cannot) offer a philosophical foundation for education. Kierkegaard, the founder of Existentialism, wrote and taught of man's inner freedom to direct his own life. Existentialism (there is a wide spectrum of ideas in this philosophy) in general:

   a. considers man as an actor on life's stage who acts according to personal choice;
   b. considers value to consist of the morality of man's choosing freely; and
   c. finds beauty in man's capacity to function apart from the public norm.

This is what some educators (science and mathematics educators included) have mistransalted to mean, "do your own thing". In addition, many of these educators want to abandon past cultural ties in teaching, an idea that makes formal education in any form obsolete. But these very vocal extremists neglect an important aspect of Existentialism: once a choice is exercised, the individual accepts the responsibility accompanying that choice.

Existentialists that express a philosophy of education agree that education should be intrinsic--behavioral change directed from the outside only does not work well if at all.

They want education to prepare individuals to develop their capabilities as a functioning person in a world full of choices. But they do not necessarily imply that first graders (or high school seniors, for that matter) are ready to make all their choices. (27)

6. Communication is indispensible to science and mathematics. All people cannot have firsthand experiences with all events and therefore must relate their experiences to each other. But the communication skills of many students are being underdeveloped. Students at all levels (K-12) are exhibiting reading and writing abilities that are below a minimum acceptable for their level of schooling.

There is a need, therefore, to improve the communication skills of almost all students. They need to communicate properly so the transfer of knowledge will not become retarded and in time become lost. The senses are circuits or pathways through which information passes. If the capabilities of these circuits are disabled by poor reading and writing skills the final outcome may be a literacy "black-out".

Considerations - Present and Future

In education, we must consider where people are going as well as where they have been. Most citizens are not going to be working at the side of an Einstein or Rutherford or Newton but they will probably work alongside John and/or Jane Doe and will therefore need a different type of preparation in science and mathematics, one which develops within them a working understanding of the fruits of Einstein, Rutherford, and Newton and how these fruits fit in their lives.

If we do not we are headed toward a technocracy that could make C. P. Snow's "two culture" a distinct reality. In ancient times--Mesopotamia and Egypt, in particular--most people could not read, write, or cipher; they had to depend upon "scribes" to record and interpret phenomena and events for them. As a consequence, thse "common people" had to accept upon faith the information presented to and interpreted for them.

This may not seem possible in a modern culture such as ours but let's look at this idea. As science, mathematics, and related fields become understandable to a smaller and smaller percentage of our population, an ever-widening gap will develop between the scholars and practioners in science and mathematics and the "common people".

A case in point is the area of computers of other devices of analysis. If the understanding of computers--their uses and limitations--by ordinary citizens does not keep pace with the advance of computers our culture will reach a point where people will have to accept information on faith. Even today, some people accept results from a computer as being correct because they say "computers never make mistakes"; they do not know or understand the phrase, "garbage in-garbage out". Accepting the results and interpretations from computers (and their operators)--the new scribes--could become a serious problem because people will have to accept results, etc., on blind faith or reject them on the basis of emotional feelings rather than logical reasoning.

To counter this trend we need to emphasize education for scientific and mathematical literacy, a building process that uses procedures to help individuals develop and understand concepts which subsequently will give them a better background to use more sophisticated procedures to understand still more sophisticated ideas.

Scientific and mathematical literacy are not attainable in a K-12 program but the K-12 program should help individuals to build on past experiences so that they can grow toward greater maturity.

Education for literacy is a lifelong process, not a one-shot immunization. Our schools are like greenhouses where the seeds of scientific and mathematical literacy are germinated and cultivated to provide saplings for transplanting and further growth in the outside world. As Szent-Gyorgyi states:

> The time spent in school is relatively short compared to the time thereafter. I am stressing this because it is widely thought that everything we have to know to do our job well we have to learn in school. This is wrong because, during the long time which follows school, we are apt to forget, anyway, what we have learned there, while we have ample time for study. In fact, most of us have to learn all our lives, and it was with gray hair that I took up the study of quantum mechanics, myself. So what the school has to do, in the first place, is to make us learn how to learn, to whet our appetites for knowledge, to teach us the delight of doing a job well and the excitement of creativity, to teach us to love what we do, and to help us to find what we love to do. (28)

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DEVELOPING SCIENTIFIC AND MATHEMATICAL LITERACY AMONG ELEMENTARY AND SECONDARY STUDENTS

Presented by Dr. M. Agin

Rapporteur's Report

by Dr. Joseph W. Riley

The major portion of the discussion centered upon scientific literacy. An attempt was made to define scientific literacy from a variety of perspectives.

Scientific literacy might be:

1) the ability to read and interpret newspaper articles about science and technology and their implications for human existence;

2) a number of general concepts that all students should know and understand;

3) an "open mind" -- one that depends on evidence before making decisions;

4) on the decline because fewer students are enrolled in science courses; or

5) an understanding of the scientific method.

The discussion then dealt with the acquisition of scientific literacy. Some comments follow:

1) Teacher preparation: many present teachers do not have strong backgrounds in science and mathematics. Present elementary teachers often like and enjoy children but are turned off by quantitative subject

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matter. Perhaps general concepts taught to students should also be taught to teachers in science and methods courses. The skills that teachers have determine what their students will do.

2) Teachers should be encouraged to be "life-long" learners. They should continue to update their backgrounds. Interested teachers do a better job.

3) Teachers may need continuing, paid inservice as in industry.

4) Curriculum Development: Surveys show that much of the content taught is determined by the textbook, not the teacher. If the teacher has a broad background, the teacher can better select what is to be taught. Possibly 3 or 4 different texts should be available in every classroom. This would provide a broader base of materials from which to choose.

Curriculum could be the responsibility of the State, school district, or individual teacher. A State curriculum guide would provide suggested topics and teaching strategies. The teacher should be free to utilize his own personal strengths and local resources.

BIOLOGY PREPARATION OF PROSPECTIVE ELEMENTARY TEACHERS

N. Jean Enochs
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I. Introduction

- A. Goals, Content and Methodology in Biology Courses for Preservice Elementary Teachers.
- B. The Biology Program for Preservice Elementary Teachers at Michigan State University.

II. Discussion of Selected Concerns

- A. Instructional Strategies and Performance.
- B. Modeling Appropriate Methodology.
- C. Student Reports of Difficulty and Time Requirements.
- D. Student Appreciation of the Value of Biological Science for Promoting Personal and Intellectual Growth.

III. Proposals for Addressing Areas of Concern

- A. Study of Students.
- B. Further Individualization.
- C. Modification for More Concrete Experience Leading to Concepts.
- D. Restructuring for Awareness of Affective Domain.
- E. Research on Biology and Intellectual Growth.
- F. Articulation of the Biology Program for Elementary Teachers.

IV. Appendices

- A. A Model Biology Course proposed by Frosch, 1973.
- B. Biological Science 202 Course Information.
- C. Student Instruction Rating System Results from Spring, 1976.
- D. Instructor Constructed Course Evaluation Form Results from Winter, 1977.
- E. Student Background Questionnaire Results from Winter, 1977.

BIOLOGY PREPARATION OF PROSPECTIVE ELEMENTARY TEACHERS

Dr. N. Jean Enochs

I. INTRODUCTION

Any analysis of the biology content of the science preparation of elementary teachers must consider not only the goals of the ideal science program, but those of the overall program for teachers. The breadth of training necessary for elementary teachers makes obligatory a rationale for the program which makes explicit the interrelation of each of several areas of knowledge which the elementary teacher must master. This paper is written in the hope that the discussion of the biology preparation of elementary teachers at Michigan State University will facilitate the improvement of biology instruction and its integration into the overall curriculum of some of the most influential graduates of the university, the elementary school teachers.

A. GOALS, CONTENT AND METHODOLOGY IN BIOLOGY COURSES FOR PRESERVICE ELEMENTARY TEACHERS

Teacher education programs in colleges and universities of Michigan almost invariably include a course in biology even though few statements of goals, content or methodology of such courses can be found in the literature apart from the statement that they should contribute to the liberal education or science literacy of the teacher. The most complete statement was published in 1963 by the National Association of State Directors of Teacher Education and Certification (NASDTEC) and the American Association for the Advancement of Science (AAAS). This basic source Guidelines for the Science and Mathematics Preparation of Elementary School Teachers in Guideline IV, Subject Matter in Science and Mathematics suggests that, "it is essential that scientific inquiry be stressed in all science and mathematics courses designed for prospective elementary school teachers," and that this can be done by providing "opportunities to increase understanding of problem solving, critical thinking, and methods of inquiry and discovery in science and mathematics." Specifically, biology instruction should

> "present a coherent view of the field of Biology and also focus on aspects of the field which are most meaningful and useful for future work with elementary school students. Such foci are:
>
> A. Kinds of living organisms--microbes, plants and animals;
> B. The functioning of organisms, including complementarity of structure and function;
> C. Growth and development of organisms, including genetic continuity; and
> D. Interrelations of organisms and environment.
>
> In organizing the foregoing aspects of biology into a coherent view of the field, there are three essential considerations. The first is the reciprocal relationship between biological inquiry and the development of biological knowledge.... The second essential is to show the interrelationships of the various areas of biology.... The third essential consideration is to stress the interrelationships between biology and other disciplines." (NASDTEC-AAAS, 1963)

A brief treatment of biology is found in the AAAS document, Preservice Science Preparation of Elementary School Teachers published in 1970 which suggests ten topics for the college science experiences of elementary teachers: composition and characteristics of matter; interactions of matter; conversion of matter; conversion and conservation of energy; growth and reproduction; evolution and genetics; ecology; human perception, learning and behavior; conceptual structure and world view, the development of scientific ideas; and the social implications of science. The methodology suggested in the first five guidelines of this publication requires that 1) elementary teachers be taught in the same style of open inquiry that is encouraged in elementary science programs, 2) an appreciation for the historical, philosophical, and current significance of science to society and positive attitudes about science be developed, 3) competence in inquiry skills or processes of scientific inquiry be developed, and 4) a capacity and disposition for continuous learning capable of affecting existing attitudes, ideas and teachings be developed in elementary teachers.

More recently a survey relating to biology curriculum and elementary teachers was carried out by Dorothy Frosch (1973) in colleges and schools of Oklahoma. College introductory biology faculty (CBF) and preservice elementary teachers (ET) ranked 40 biology principles by their significance for content in a general education biology course and secondly, 40 statements of methodology and philosophy. As indicated in Table One, seven principles were identified by the college faculty as needing the strongest emphasis; four of the seven relate to ecology and the remaining three dealt with common life processes, cellular function and homeostasis. While the elementary teachers did not rank any principle as being of first order importance, they did rate the first six principles as somewhat important.

Table Two presents mean rankings given content areas to be emphasized in a preservice biology course for elementary teachers. While both groups rank ecology as of first order importance, significant differences exist between their rankings of Health and Disease (elementary teachers giving it a significantly higher priority) and Evolution (elementary teachers giving it a significantly lower priority). On

TABLE 1

RESPONSES TO COURSE CONTENT STATEMENTS OF THE COLLEGE BIOLOGY FACULTY AND ELEMENTARY TEACHERS IN ORDER OF INCREASING MEAN RANK OF THE COLLEGE FACULTY

Opinionnaire Statement	CBF* (mean rank)	ET** (mean rank)	DIFFERENCE IN MEAN RANK
The living world is made of ecosystems	1.73	2.87	1.14
Energy has a unidirectional flow through ecosystems	1.76	2.63	.87
Man is a powerful ecological force	1.79	2.08	.29
The earth has finite space, material and available energy	1.90	2.19	.29
Life processes are common to all living organisms	1.92	2.39	.47
Cell functions provide basic information about life functions at all biological levels	1.95	2.47	.52
All living systems are actively engaged in maintaining homeostasis	1.99	3.08	1.09

TABLE 2

OPINIONNAIRE RESPONSES TO AREAS WHICH SHOULD DEFINITELY BE EMPHASIZED IN ANY COLLEGE GENERAL BIOLOGY COURSE

Area	CBF (mean rank)	ET (mean rank)
Ecology (plant and animal)	1.85	1.80
Ecology (human)	1.91	1.67
Genetics	2.17	2.60
Social implications	2.18	2.64
Reproductive biology	2.21	2.55
Cell biology	2.32	2.70
Evolution	2.51	3.55
Molecular biology	2.80	3.00
Behavior and its biological basis	2.87	2.39
Human disease and health	2.89	1.73
Plant and animal physiology	2.90	2.26
Kinds of organisms	2.96	2.29
Development	3.08	2.32
History of life	3.20	2.98

being asked about the most appropriate theme around which to build a general education biology course, the college biology faculty ranked ecology most appropriate (Table Three).

The major outcomes of the rankings of methodology statements were suggestions that in a biology course for elementary teachers 1) behavioral objectives be specified, 2) a laboratory is central to developing curiosity, science process and inquiry skills, 3) group discussions of study problems further develop critical analysis ability, and 4) some lectures be given centering on basic biological principles and difficult topics. On the bases of the content and methodology rankings of the two groups, Frosch developed a Model Biology Course which is presented in Appendix A.

Though there are many papers in the literature relating to specific aspects of the science preparation of elementary teachers, these three seem to be the most comprehensive in dealing with the goals, content and methodology of the biology courses commonly taken by preservice elementary teachers.

B. THE BIOLOGY PROGRAM FOR PRESERVICE ELEMENTARY TEACHERS AT MICHIGAN STATE UNIVERSITY

The science and mathematics program for elementary education majors at Michigan State University consists of three terms of a Natural Science sequence, Foundations of Arithmetic for Elementary Teachers (201), Biological Science (202), Foundations of Physical Sciences (203), Teaching Mathematics in Elementary Grades (325E), and Teaching Science in the Elementary and Middle School (325F).

Thus approximately 1/6 of the elementary teachers' college work is devoted to 1) building a knowledge of the goals, structures and tools of science and mathematics, and 2) establishing confidence in the teachers'

TABLE 3

OPINIONNAIRE RESPONSES TO A CENTRAL THEME AROUND WHICH TO DEVELOP A GENERAL EDUCATION BIOLOGY COURSE

Theme	% of Total CBF
Ecology (plant and animal)	25.64
Evolution	17.95
Cell biology	14.10
Ecology (human)	10.26
Social implications of biology	8.97
Kinds of organisms	3.85
Molecular biology	2.56
Genetics	2.56
Plant and animal physiology	1.28
Human disease and health	1.28
History of life	0.00
Reproductive biology	0.00
Development	0.00
Behavior and its biological basis	0.00

ability to help children develop their knowledge of the goals, concepts, and tools of science and mathematics in learning about and living in the natural world. These two tasks are as highly interrelated and difficult to separate as the relations between the science and mathematics preparation of teachers and their overall preparation for teaching. The necessity for offering courses on specific topics tends toward a separation of the personal, intellectual and professional growth of students which is artificial and often detrimental to the growth sought. Rather than viewing the science and the mathematics component of teacher education as only teaching science and mathematics information and methods for transmitting that information, this component must be viewed as contributing to the intellectual, personal and professional development of the teacher.

The Natural Science sequence was developed to give the beginning college student an understanding of the basic methods of science and its contributions to life and thought. Several biological concepts and topics are dealt with in each of the alternative tracks; however, only the topics of reproduction and genetics and the concept of biological evolution are integral to each of the tracks.

Biological Science 202 builds upon these foundations utilizing the concept of ecosystems as a central theme and classification as a subordinate theme. The first two weeks' topics (structuring biology, the nature of science, the nature of life, physical and chemical aspects of life, and classifying) establish the concept of ecosystem and serve to introduce a study of the anatomy, physiology and development of producers, consumers, and decomposers over the next five weeks; this, culminates in a return to ecology and the related problems of society during the last two weeks of the course.

The course methodology provides one hour of lecture, two hours of group laboratory, open hours for independent laboratory study and a quiz each week, plus a comprehensive final examination. A more thorough description of the course methodology and content can be found in the attached course information sheet, Appendix B. This course is offered four quarters per year and had an average enrollment of approximately one hundred students per quarter over the last year.

The biology content of the science methods course varies from instructor to instructor, but it might be characterized as building on the preceeding courses in emphasizing ways of teaching the concepts and processes of science in elementary and middle schools. Although there are certainly points of articulation between biology instruction and areas of the elementary teacher curriculum outside of Science and Mathematics, these junctures have not been made explicit to date.

In summary, the total biology preparation of elementary teachers at Michigan State University is equivalent to approximately two quarters' instruction (elements of the Natural Science sequence, Biological Science 202, and elements of the Science Methods course). Elementary teachers with majors or minors in science take in addition 30 or 12 quarter credit hours of science, respectively, some of which may be biology. Courses may be selected from the areas of Astronomy, Botany, Chemistry, Physics, Fisheries and Wildlife, Geology, Zoology, Resource Development, Mathematics, and Statistics.

II. DISCUSSION OF SELECTED CONCERNS

Comparing ideal biology instruction of elementary teachers with that at Michigan State University elicits many emotions, responses and questions; however, rather than pursuing a comprehensive analysis of the strengths and weaknesses of the program, we will focus on areas of concern which arise from eight years of teaching the course and continual comparison of the ideal and real. These concerns are 1) the failure of available self-pacing and individual tutoring to bring each student to an acceptable level of performance, 2) the differences between the methodologies used in teaching biology at the college level and those most appropriate for elementary schools, 3) the consistent response from a majority of students completing biology courses that they require too much time and study and, 4) the attitude of students toward biology and biology teaching and their propensity toward teaching biological science in the crowded curriculum of most elementary schools.

A. INSTRUCTIONAL STRATEGIES AND PERFORMANCE

The Biological Science 202 course methodology is commonly designated as an "audio-tutorial" (AT) approach being characterized by a reduction in lecture time in order to give students more laboratory experience in small groups and more individual tutoring by the senior instructor via audio-tapes in a laboratory setting. The rationale for this approach posits that although students come to a course with different backgrounds, abilities, and skills, all can reach an acceptable level of performance by taking advantage of unlimited laboratory hours and help on a one-to-one basis as necessary. It would be expected that students with poorer backgrounds will spend more time carrying out learning activities, asking questions and repreating explanations than will students with average

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and superior backgrounds and by doing so they also will reach an acceptable level of understanding.

From data presented in Table Four we can infer that grades in the course correlate with time spent in the laboratory. Table Five indicates that students, who on the basis of their college grade point average (GPA) can be predicted to need more help, often spend less time in the independent laboratory than more able students. One can also infer that the least able students are not able to use the time they do spend effectively. This is not peculiar to 202 but is often reported in AT courses (Fisher and MacWhinney, 1976). Modification of initial methodology to include two hours (rather than one) of small group instruction and further, to schedule students to two hours in the independent laboratory with additional open laboratory hours were both attempts to give average and poor students the support and motivation necessary to take full advantage of the open laboratory time. The average time spent in the independent laboratory per tape shifted from 63.6 minutes in Spring 1976 to 70.2 minutes in Fall 1976 when the second modification was made (Smith and Enochs, 1974). However, the problem of enabling students with average and poor backgrounds to spend as much time in the laboratory and to spend it as effectively as more able students do remains a problem.

B. MODELING APPROPRIATE METHODOLOGY

The AAAS guidelines for preservice education of elementary school teachers referred to above suggest that, "above all else, the elementary teacher should be a liberally educated person.... All teachers must be liberally educated persons, and consideration of this requirement must

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TABLE FOUR

AVERAGE MINUTES SPENT IN LABORATORY PER TAPE BY STUDENTS RECEIVING DIFFERENT GRADES, FALL 1976

Grade	Minutes	Number
0.0	73.8	10
1.0	73.8	4
1.5	67.2	7
2.0	61.8	26
2.5	62.4	30
3.0	78.8	32
3.5	79.8	17
4.0	79.2	19

TABLE FIVE

AVERAGE MINUTES SPENT IN LABORATORY PER TAPE BY STUDENTS WITH DIFFERENT GPA, FALL 1976

GPA	Minutes	Number
0.0-1.00	79.8	3
1.10-1.99	69.6	9
2.00-2.50	67.8	36
2.51-3.00	70.8	48
3.01-3.50	73.8	38
3.51-4.00	81.6	11

be foremost in the development of teacher education programs." At the same time they also assert:

> "The adage that we 'teach as we were taught' is not without foundation. If elementary teachers are to present sciences as an exciting exploration of the natural world where pupils have ample opportunity to interact with that world, to ask questions of nature as well as of people, and to discover that even young people can find order there, teachers, too, must have such opportunities. What is done in college science courses will materially affect the way that elementary teachers teach science." (AAAS, 1970).

In attempting to provide science literacy as an integral part of a liberal education, college level biology courses typically present the concepts of biology in an abstract way in lecture and demonstrate the concepts in a laboratory experience. While this procedure allows mature students to develop their ability to reason from principles, it is not sufficient for children whose reasoning abilities are limited to dealing with concrete objects. For children, direct observation of many examples of a phenomenon is necessary to develop a principle; their reasoning is related to concrete objects rather than the abstract principles. Because elementary teachers tend to teach as they were taught, the ways in which concepts are presented are important, as well as the concepts themselves. The fact that it is more time consuming to develop concepts from concrete experience than from abstractions, coupled with the fact that an attempt is being made to deal with all the basic principles of biology in one quarter, constrain the biology professor to teach in a style which is inappropriate for elementary school teaching. Hence, the adage "teach as I say, not as I do."

Two basic questions arise; one, can the current course be altered to give more attention to student inquiry, processes of science and modeling teaching strategies appropriate for elementary school teaching and simultaneously emphasize the basic concepts of biology? and two, can the structure of the program of biology and science instruction for elementary teachers be modified to better facilitate the attainment of both these goals?

The close interrelation of the liberal education of the teacher and his or her professional education is apparent. While the concern for modeling appropriate teaching methods must not be allowed to overshadow a concern for science literacy, these methodologies, e.g., the use of inquiry strategies in developing skill in the processes of science, are not inconsistent with science literacy. Ways of integrating the two must be found in the program of biology instruction as well as in the broader science and mathematics curriculum and teacher education program as a whole.

C. STUDENT REPORTS OF THE DIFFICULTY AND TIME REQUIREMENTS

Student responses to the course are gathered every quarter using, on occasion, the Michigan State University Student Instruction Rating System (SIRS) and routinely an instructor constructed instrument for obtaining student evaluations. In addition to the more positive evaluations listed below, both of these measures indicate that the course is demanding. In responding to the SIRS question question 6, "how would you rate the course load taking into consideration the course level and the number of credits earned", two percent answer "easy", thirty-one percent "moderate", fifty-three percent "rather demanding", and seventeen percent "extremely demanding". (See Appendix C for the SIRS evaluation from Spring, 1976). The data from the instructor constructed Course Evaluation from Winter, 1977 which is attached as Appendix D, elicited consistent responses. On item five, 83% of the students answered affirmatively that, "this course required more study than any other course on my schedule"; in item twelve, 71% affirmed, "the subject matter of the course is challenging," and on item thirty, "compared with other courses I have taken, the difficulty of this course was: very easy 1%, easy 4%, about average 26%, difficult 45%, very difficult 23%".

On item thirty-four the same students report the number of hours spent studying outside of class per week were: less than 2 hours - 10%; 3-5 hours - 44%; 6-8 hours - 18%; 9-10 hours - 10%; over 10 hours - 8%. When one assumes that it is likely the superior students who spend over 9 hours per week (Table Five), and predicts that it would require even more time for a poor student to reach an acceptable level of performance, a reason for student frustration becomes apparent. These students may suppose that the course is based on the premise that "learning, like athletics, benefits from regular exercise to the point of exhaustion" (Krockover, 1975).

Student responses to question 10 of the Student Background Questionnaire (Appendix E) indicate the grade that they "realistically expect to receive" in the course on the first day of class. This data along with the actual grades received are presented in Table Six.

TABLE SIX

EXPECTED AND ACTUAL GRADES FROM WINTER, 1977

Grading Scale	0.0 - 1.5	2.0	2.5	3.0	3.5 - 4.0
Expected	0%	3%	15%	50%	32%
Actual	15%	8%	24%	31%	20%

It is apparent that many students not only find the course difficult and time consuming but they may also be disappointed in their performance.

The current structure of the biology program for elementary majors allowing one quarter for biological science produces a conflict between concern for students who experience these difficulties and commitment to liberal education and a thorough preparation of students for biology teaching from kindergarten through grade eight.

D. STUDENT APPRECIATION OF THE VALUE OF BIOLOGICAL SCIENCE FOR PROMOTING PERSONAL AND INTELLECTUAL GROWTH

Even though 89% of the students completing the course report that they have become more aware of living things (item 1), 85% support the methodology of the course (item 8), 73% respond that they learned a lot (item 19), and 85% found the course interesting (item 31), the negative experiences with time, difficulty and grade of many of the students raise questions regarding their attitude toward biology and biology teaching. One might infer that the less able students will be unable to teach elementary biology and enjoy it because they have had to work hard and did not excell. Alternatively, one might infer that the positive feedback of intellectual and personal growth which they experience in working and learning may allow these students to see the utility of biological science for promoting this growth in children. More information is needed regarding the students' affective responses to Biological Science 202 and their ultimate behavior as elementary teachers.

III. PROPOSALS FOR ADDRESSING AREAS OF CONCERN

It is apparent that the foregoing concerns are not unique to Michigan State University, and it is hoped that the proposed responses will also be generally applicable. The concerns are highly interrelated and the following proposals for addressing the concerns will be correspondingly synergistic. We propose:

A. A thorough study of background, intellectual skills, attitudes, and motivation of students enrolling in Biological Science 202 as individuals and as groups with differing backgrounds, abilities, and aspirations.

B. Development of a truly individualized instructional program which will provide different instructional programs for different students based on the knowledge of students and an ability to predict their learning behavior gained in proposal A.

C. Modification of the course to provide inquiry experience and process skill development on a concrete level as well as more abstract levels. It is not expected that all didactic presentation will be eliminated, but that opportunities for experiential learning will be increased. Not only will these modifications model appropriate ways of teaching biology, but it is expected that they will also be a more appropriate way to stimulate the intellectual development of the less able students in 202.

D. Design of instruments, procedures, and instruction which will allow a more thorough monitoring and care for the affective aspects of the course and the personal growth of students.

E. Participation in the research programs of the Science and Mathematics Teaching Center which have as a goal making explicit ways in which science promotes intellectual growth.

F. Development of a system of people who will exchange information, supply feedback on effects of courses, and most importantly will facilitate the development of a program of biology and science instruction which is carefully related to other courses within the university and fully responsive to changes in schools and society. This system should include students; the staff of the courses; faculties of the Science and Mathematics Teaching Center, College of Education, and Biological Science Departments; former students and elementary teachers; school administrators; professional organizations; publishers; the State Department of Education and all who have a sincere interest in students and biology instruction.

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Krockover, Gerald H., 1975. "Science Education for the Future: Tomorrow Never Comes," School Science and Mathematics 75 (7): 639-644.

NASDTEC-AAAS, 1963. Guidelines for Science and Mathematics in the Preparation Program of Elementary School Teachers, Miscellaneous Publication 63-7, Washington, D.C.

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APPENDIX A

A MODEL BIOLOGY COURSE, PROPOSED BY FROSCH (1973)

I. Statement of the general biology course objectives.

II. Statement of behavioral objectives both for the classroom and the laboratory.

III. Select or devise laboratory experiments designed to increase the student's skill in scientific processes (observation, measurement, formulating hypothesis, etc.). The laboratory should also provide the kind of environment which stimulates student curiosity and encourages scientific investigation.

IV. Coordinate the laboratory with classroom lectures.

V. Develop audio-tutorial laboratory lessons and a module unit for biological areas in which only some of the students are unprepared. (example: chemistry, basic measurement).

VI. Set aside an area near the laboratory which contains reference texts, 8 mm slide projectors and tables for student conferences and study.

VII. Ecology is the central theme. The lecture and laboratory is developed around the following units:

A. Activities of Life

1. Life processes common to all living organisms.
2. The four basic organic compounds found in living components.
3. Homeostasis.
4. Control by enzymes.
5. Cell physiology.
6. The functions of unicellular organisms.
7. Microorganisms.
8. Photosynthesis.
9. Respiration.
10. Plant and Animal Physiology.

B. The Past, the Present and the Future.

1. Reproduction.
2. Development.
3. Heredity.
4. Genes.
5. Genetic Code.
6. DNA and RNA.
7. Evolution.

C. Plant and Animal Ecology.

1. Classification.
2. Kinds of organisms.

3. Order is a constant theme.
4. Living World is made of ecosystems:
    a. populations
    b. communities
    c. biomes
5. Flow of energy.
6. Cycling of nutrients.
7. Population growth.

D. What is Man's Place in the World?

1. Earth has finite space.
2. Control of diseases.
3. Control of pests.
4. Man as a strong ecological force.
5. Man's social interactions.

VIII. The course should be taught using the inquiry, lecture, and individual study approach. The inquiry method should be strongly emphasized in the laboratory. Inquiry may be used in discussion groups which devise problems and techniques to secure answers. Group study problems could be utilized to engage the students in active investigation providing an opportunity to approach the study of science in ways that have meaning for them.

Students may present current problems to the class for clarification, further investigation, and critical analysis. This activity could be used to develop desired scientific attitudes.

IX. Some lectures should be prepared but these should be developed around basic principles and those areas requiring special help for better understanding.

APPENDIX B

Biological Science 202 COURSE INFORMATION Spring 1977

Texts

Keeton, William T., Elements of Biological Science, 2nd Edition, New York: Norton, 1973. (suggested)

Burnett, Fisher, Zim., Zoology, New York: Golden Press, 1958. (required)

Burnett, Alexander, Zim., Botany, New York: Golden Press, 1970. (required)

Biological Science 202 Study Guide, 1975, Unpublished. (required)

There are several copies of these textbooks on reserve in the Materials Center in Room 102 McDonel Hall which also has other Biology books.

Introduction

This course is designed for the pre-service elementary school teacher; however, it is open to any student who wants an introductory Biological Science course. The purpose of this course is to help you 1) to learn basic biological facts, concepts, and skills; 2) to think scientifically and 3) to develop confidence in your ability to teach Biology as a science in elementary schools. It is our conviction that you, the learner, must actively learn, that teachers can only help you learn, and secondly, that our ability to ask questions and find answers, to think and make decisions, to take responsibility for yourself is most important. Therefore, we have designed the course to allow you to develop yourself as you learn Biological Science with as much help or as little help as you need. As instructors we propose to help you by 1) suggesting what you should learn by presenting objectives; 2) designating one or more learning activities by which you may learn to fulfill the objectives; 3) facilitating your going beyond minimal standards to develop your own interests by suggesting and encouraging independent activities; 4) evaluating and documenting your success at learning and performing in the Biological Sciences. Your role is to learn actively, to take responsibility for your learning to the limits of your capacity. You will be able to pace yourself through an individual study session and decide to what degree you wish to pursue the subject. If you have little background in Biology, you may ask questions and repeat techniques without slowing others who may already be familiar with some of the material. If you already know the material specified to be learned you may skip over the designated learning experiences at your discretion to ask questions, investigate and go beyond the minimal levels of mastery by independent activities. In any event the learning regiment that you choose is self-tailored to meet your needs and aspirations.

Course Methodology

The procedures for this quarter have evolved over a five year period as students have tried and responded to this approach to learning. We have made significant changes in the course on the basis of student suggestions; and we anticipate continuing the development of the course on the basis of your experience this quarter. The general description of the procedure follows:

Lecture Session (LS): Monday 9:10.	1 hour
Small Assembly Sessions (SAS): MW or TT.	2 hours
Individual Learning Session (ILS): MW or TT. . . . . (or as long as you need)	2 hours
Evaluation Session (ES): Friday, 9:10.	1 hour
Minimum . . .	6 hours/wk.

You are scheduled to attend a Lecture Session (LS) on Monday in which information suited to lecture rather than laboratory or discussion session is presented. The context for the weeks work will be set in this session and it will be heavily content oriented and coordinated with the assigned reading concerning the biological facts and concepts of the week. It may be used for guest lecturers on biological topics or of long movies, and it is the only occasion where all the students meet with the senior instructor at the same time.

The Small Assembly Session (SAS) meets in 106C McDonel Hall and brings together 22 students for group interaction with the aspects of the course that may best be learned in this manner. This session os oriented toward elementary school "sciencing" and techniques for maintaining and investigating animals, plants, and microorganisms in the classroom. In it you will become acquainted with the instructor who is personally concerned with you and your progress through the course.

From there you will move into the heart of the course, the Individual Learning Session (ILS). You should have read over the objectives for the week and assigned readings before coming to the Learning Center to begin the learning activities which can best be done individually. You will be able to follow the programs at your own rate, with or without further explanation from the instructor and receive help on a one-to-one basis. You may spend as much or as little time in this session as you need with as much or as little assistance as you need in learning to fulfill the week's objectives and going beyond the minimal requirements to do independent activities. You should also use this time to ask the instructors questions about the lectures, assigned reading or any aspect of the course which is unclear to you. Since we anticipate the students with an average background (1 year of high school biology) will spend about 2 hours in the ILS, we strongly urge you to begin the weekly program early and to finish it another day rather than doing it all in one sitting. There will be a tally of how many students are in the Learning Center at each hour so that you may know when the slack times are and try to come then for any extra time you need. You will also find on the bulletin board a schedule showing when your SAS instructor will be on duty in the ILS.

You are also scheduled for an Evaluation Session (ES) on Friday. During this hour you will be given a quiz over the week's objectives using pictures, diagrams, objects and specimens from the GAS, SAS, ILS and assigned reading. It is anticipated that this session will be both a testing and learning situation for you. There is no mid-term examination requirement.

Attendance

Students are expected to attend all sessions: absence is considered to be serious. Absences due to ill health or death in the family are excusable and can be made up by contacting your instructor on your return. The privilege of makeup work is not guaranteed under any other circumstance. The makeup work for the ES will require the absentee to write a 2-3 page report which demonstrates comprehension of all the objectives for the unit and/or completing requisite quizzes. The makeup work must be done within one week after permission for it has been granted. Students who miss more than two week's work during the quarter will be required to obtain written permission from Dr. Enochs before they can make up the quizzes or continue in the course.

Grading

Evaluation of your progress in the course is necessary for you to see how successful your learning strategies are in relation to the stated objectives and the performance of other students in the course, in order that you may modify your strategies if necessary for you to reach your goals. The ES gives the basis for this feedback; you should feel free to discuss your progress with your instructor and/or with the senior instructor, Dr. Enochs. Your grade in the course will be determined by your performance on class assignments, independently selected activities, and your score on the written tests and final examination. The weighting of these activities and the grading scale follows: Nine weekly tests will be given and you will be allowed to drop your lowest grade.

Weekly tests - (40 points each) 320 possible
Final Exam - 80 points possible
Assignments - 20 points possible
Independent Activities - 20 possible

378-420 points (90%) = 4.0
347-377 points (85%) = 3.5
336-356 points (80%) = 3.0
315-335 points (75%) = 2.5
294-314 points (70%) = 2.0
273-293 points (65%) = 1.5
252-272 points (60%) = 1.0

Course Content

Elementary biology teachers must be familiar with the basic facts, concepts and principles of biology but that is not enough. Teachers also need to be proficient in the processes of science such as observing, measuring, classifying, using numbers, predicting, inferring, communicating, hypothesizing, experimenting and interpreting data. Even that is not enough, teachers must be skilled in handling living organisms and laboratory apparatus. Hopefully, teachers will be curious and investigative, and have a positive attitude toward sciencing. This seems like an impossibly big order, but it is with these ideas in mind that we have designed this course. It is finally enough that you are fully responsible and creatively free in helping youngsters learn.

It is our belief that you will benefit from your college career in proportion to the degree to which you are directly involved with your learning. We feel that this method may allow you more direct involvement with the subject matter and at the same time give you more individual attention from the instructors and encouragement to go beyond the minimal requirements. We will be interested in your reaction to this methodology, and we will be responsive to your observations and suggestions as we try to make the time spent in this course profitable to you.

Biological Science 202 Course Outline Spring 1977

Week	Ecological Topics	Organism Survey	Readings*
1 April 4-8	Introduction LS - Organizing Biology - Nature of Science #1. The Microscope SAS - Classifying Nature of Life	Animals #2. Protista Protozoa Porifera Metazoa Coelenterata Platyhelminthes Aschelminthes	B: p. 10, 11 Z: p. 4-9 ** p. 18-21 OS p. 24-39 K: p. 1-10 p. 66-69 OS Handouts: Levels of Organization
2 April 11-15	LS - Chemical Bases of Life #4. Cells SAS - Physical Bases of Life - Models of Elem. Science Teaching	#3. Mollusca Annelida Echinodermata	B: p. 78-83 Z: p. 22-23 p. 40-44 OS K: p. 13-31 p. 35-46 p. 45-56 p. 62-66 p. 508-512 OS p. 517-521 OS Handouts: Chemical Bases of Life
3 April 18-22	Autotrophic Life LS - Photosynthesis #6. Producers SAS - Insects - Photosynthesis (Contracts due) Assignment - 1	#5. Arthropada crustacea millipeds centipeds arachnids insecta	B: p. 4-9 Z: p. 45-64 OS K: p. 57-62 p. 82-84 p. 127-137 p. 71-75 p. 95-101 p. 118-119 Handout: Photosynthesis
4 April 25-29	Heterotrophic Life LS - Homeostasis I #8. Consumers I SAS - Consumer Anatomy 1 - Consumer Anatomy 2	#7. Chordata I fish amphibians reptiles birds	Z: p. 65-81 OS p. 114-123 K: p. 31-34 p. 102-115 p. 119-126 p. 137-161 p. 521-532 OS Handout: Respiration
5 May 2-6	LS - Respiration #10. Consumers 2 SAS - Animal Behavior 1 - Animal Behavior 2 Assignment 2	#9. Chordata 2 mammals	Z: p. 82-96 OS p. 97-113 p. 84-87 K: p. 200-208 p. 226-231 p. 234-239 p. 532-536 OS Handout: Respiration
6 May 9-13	Continuity of Life LS - Molecular Reproduction #12. Reproduction I SAS - Molecules and Cancer - Microorganisms in the Classroom Assignment 3	Plants #11. Decomposers Monera blue-green algae bacteria Protista fungi	B: p. 12-18 p. 24-41 OS p. 76-77 p. 88-117 p. 129-131 K: p. 279-291 p. 320-341 p. 165-177 p. 448-459 OS p. 469-475 OS Handout: Protein Synthesis

Week	Ecological Topics	Organism Survey	Readings*	
7 May 16-20	LS - Homeostasis 2 #14. Reproduction 2 SAS - Chick Development - Human Development	#13. Protista algae Metaphyta mosses ferns conifers	B: p. 19-27 OS p. 42-55 p. 104-105 Handout: Menstrual Cycle	K: p. 177-199 p. 341-356 p. 460-469 OS p. 475-486 OS
8 May 23-27	Interaction of Organisms LS - Cycles #16. Ecology 1 SAS - Indoor Plants - Field Trip (Independent Work Deadline) Assignment 4	#15. Angiosperms	B: p. 56-63 p. 106-115 p. 142-156 p. 145-155 Handout: Carbon Cycle Nitrogen Cycle	K: p. 248-275 p. 392-402 p. 418-431 p. 486-489 OS
9 May 30 June 3	LS - Holiday #18. Ecology 2 SAS - Population Ecology - Alternative Futures	#17. Organism Review	Z: p. 9-17 p. 138-144 B: p. 132-141 Handout: Organism Review	K: p. 402-418 p. 388-390 OS p. 361-391 OS

FINAL EXAM: Thursday, June 9, 1977 12:45 - 2:45 p.m. in McDonel Kiva

*Books for reading designated. Z = Zoology, B = Botany, K = Keeton

Boxed pages and handouts are required reading others are explanatory or supplementary

** OS = readings related to the Organism Survey.

APPENDIX C. Student Instruction Rating System Results from Spring, 1976

Michigan State University

Student Instructional Rating System Level III

1. How worthwhile were the class sessions (lectures, discussions, labs., etc.)?
   1. not worth going to - 5%
   2. nothing special - 26%
   3. worthwhile to attend - 54%
   4. very worthwhile and beneficial - 14%

2. How would you rate the instructor's style in presenting course material?
   1. inadequate 11%
   2. sufficient 58%
   3. above average - 26%
   4. superior - 5%

3. How would you rate the instructor's style in presenting course material?
   1. very boring - 7%
   2. somewhat monotonous - 22%
   3. satisfactory - 51%
   4. interesting - 18%
   5. stimulating - 1%

4. How well was the instructor able to respond to questions?
   1. more confusing than helpful - 6%
   2. adequately 26%
   3. reasonably well - 43%
   4. very thoroughly and clearly - 23%
   5. no opportunity to ask questions - 1%

5. How logical and organized was the instructor's direction throughout the course?
   1. confusing and undirected - 5%
   2. a little confusing - 10%
   3. good organization - 68%
   4. exceptionally well organized - 9%

6. How would you rate the course load, taking into consideration the course level and the number of earned credits?
   1. easy - 2%
   2. moderate 31%
   3. rather demanding - 53%
   4. extremely demanding - 17%

7. How would you rate the difficulty of the instructor's grading?
   1. easy - 1%
   2. average - 70%
   3. difficult - 20%
   4. extremely difficult - 5%

8. How well did the exams test your knowledge of the course material?
   1. poorly - 16%
   2. fairly well - 57%
   3. very well - 27%
   4. there were no written exams

9. How would you rate the instructor's attitude toward teaching the course?
   1. very apathetic - 1.2%
   2. indifferent - 2.5
   3. interested - 74%
   4. very enthusiastic - 20%

10. How well did the instructor supplement the course material through use of examples, personal analogies, etc.?
   1. poorly - 7%
   2. adequately - 52%
   3. effectively - 32%
   4. very effectively - 7%

11. How would you rate this instructor on an overall scale?
   1. poor - 4%
   2. below average - 10%
   3. average - 58%
   4. very good - 27%
   5. excellent - 1%

12. What is the course number of this class?
   1. 000 - 299 - 94%
   2. 300 - 499 - 6%
   3. 500 - 699
   4. 700 - 799
   5. 800 - 999

13. What is your class standing?
   1. freshman - 2%
   2. sophomore - 31%
   3. junior - 43%
   4. senior - 14%
   5. graduate or other

14. Was this class required in your degree program?
   1. yes - 93%
   2. no - 2%
   3. I haven't declared a major - 1%
   4. I am not sure

APPENDIX D.

Instructor Constructed Course Evaluation Form Results

from Winter 1977

For questions 1-29 use the following scale to select your response to the statements presented.

1. I strongly agree with this statement.
2. I moderately agree with this statement.
3. I am undecided about this statement.
4. I moderately disagree with this statement.
5. I strongly disagree with this statement.

Statements

Statements	SA	MA	U	MD	SD
1. This course has made me more aware of living things around me.	35%	54%	4%	2%	4%
2. I generally enjoyed going to lecture.	7%	26%	21%	30%	15%
3. I generally enjoyed going to SAS.	20%	55%	10%	9%	6%
4. I generally enjoyed going to ILS.	8%	32%	21%	22%	17%
5. This course required more studying than any other course on my schedule.	64%	19%	3%	10%	3%
6. I knew what was expected of my in this course.	27%	53%	10%	7%	2%
7. I would have preferred to have a different SAS instructor.	10%	4%	10%	19%	55%
8. I would prefer a 3 hour lecture - 3 hour lab approach to this course.	8%	7%	16%	18%	52%
9. I frequently needed help in ILS and could find no instructor.	0%	4%	7%	45%	44%
10. I would have liked more experience in the care of animals used in the classroom.	16%	35%	21%	20%	8%
11. Weekly written quizzes are helpful.	34%	40%	18%	7%	1%

		SA	MA	U	MD	SD
12.	The subject matter of the course is challenging.	36%	35%	20%	9%	0%
13.	I would like more opportunities for experimental manipulations in ILS.	1%	23%	32%	34%	11%
14.	There should be less repetition between lecture, lab and the assigned readings.	6%	7%	18%	38%	32%
15.	I would have liked more experience in caring for plants used in the classroom.	25%	38%	22%	12%	2%
16.	The course content was well organized.	37%	35%	14%	10%	3%
17.	The weekly quizzes were fair.	11%	26%	13%	38%	10%
18.	The lectures helped me understand the course content.	12%	30%	21%	28%	8%
19.	I learned a lot in this course.	39%	34%	16%	9%	1%
20.	The SAS sessions were useful.	34%	46%	11%	6%	3%
21.	I feel that there is ample opportunity to have questions answered in SAS & ILS.	49%	36%	10%	3%	1%
22.	I would like the SAS to be more lab (activity) oriented.	6%	21%	34%	27%	12%
23.	I thought the field trip was worthwhile.	7%	22%	38%	16%	14%
24.	I think a weekly Thursday review session would be helpful.	38%	39%	16%	7%	1%
25.	The demo table material served to reinforce the material on the tapes.	38%	50%	6%	3%	2%
26.	The displays presented the material clearly and concisely.	32%	50%	11%	6%	1%
27.	The layout of the demonstrations was attractive and pleasing to look at.	21%	43%	26%	9%	1%
28.	The use of experiments and exercises in the displays helped me understand the content.	15%	40%	22%	17%	6%

SA	MA	U	MD	SD
18%	49%	18%	4%	2%

29. I found the ILS session helpful.

30. Compared with other courses I have taken, the difficulty of this course was:
A. very easy - 1%
B. easy - 4%
C. about average - 26%
D. difficult - 45%
E. very difficult - 23%

31. I have found this course to be:
A. very boring - 1%
B. boring - 12%
C. slightly interesting - 21%
D. interesting - 46%

32. Have you heard of or observed any cheating on the weekly quizzes? (If your answer is yes please comment on the space provided).
Yes - 34% No - 74% Not Answering - 21%

33. The average time I spent in the ILS session per week was: (1) less than 1 hour - 1.1% (2) 1-2 hours - 16%, (3) 2-3 hours - 40%, (4) 3-4 hours - 22%, (5) over 4 hours - 12%, No Answer - 8%

34. The average time per week I spent studying 202 out of class was (1) less than 2 hours - 10%, 3-5 hours - 44%, (3) 6-8 hours - 18%, (4) 9-10 hours - 10% (5) over 10 hours per week - 8%, No Answer - 10%.

35. The approximate number of lectures I attended was (10 possible). (1) 1-2 - 1%, (2) 3-4 - 2%, (3) 5-6 - 6%, (4) 7-8 - 18%, (5) 9-10 - 64% No Answer - 9%.

36. The approximate number of SAS sessions I attended was (19 possible). (1) 12 or less - 0%, (2) 13-14 - 1%, (3) 15-16 - 2%, (4) 17-18 - 32%, (5) 19 - 56%, No Answer - 9%.

37. The approximate number of tapes I listened to was (18 possible) (1) 10 or less - 0%, (2) 11 or 12 - 1%, (3) 13 or 14 - 2%, (4) 15 or 16 - 3%, (5) 17 or 18 - 84%, No answer - 9%

38. When I was listening to the tapes I
(1) listen continuously without stopping for activities - 14%
(2) stopped the tape for suggested activities. - 37%
(3) listened all the way through and then did the suggested activities -30%
(4) stopped the tape for activities and then reviewed by listening to the tape most the way through again - 7%
No Answer - 12%

39. In high school I took biology (1) 0 years - 4%, (2) less than 1 year - 10%, (3) 1 year - 49%, (4) 2 years - 25%, (5) 3 years or more - 1%, No answer - 9%

40. At MSU I have taken a Natural Science sequence course (1) 0 quarters - 14%, (2) 1 quarter - 8%, (3) 2 quarters - 11%, (4) 3 quarters - 46%, (5) transferred credit or took substitute courses - 10%.

41. Excluding the Natural Science sequence, I have had college biology courses (botany, zoology, physiology, etc.) (1) 0 quarters - 68%, (2) 1 quarter - 13%, (3) 2 quarters - 6%, (4) 3 quarters - 1%, (5) 4 or more quarters - 1%.

42. My major is: A. Elementary Education - 48%, B. Special Education, - 11%, C. Social Science or Psychology - 6%, D. Child Development - 19%, E. Other - 3%, No Answer 12%

APPENDIX E. Student Background Questionnaire Results from Winter, 1977

1. My major is:

    1. Elementary education - 62%
    2. social science - 1%
    3. child development - 19%
    4. special education - 13%
    5. other - 4%

2. I have taken:

    1. no biology (botany, zoology, physiology) in high school - 8%
    2. less than one year of biology in high school - 9%
    3. one year of biology in high school - 64%
    4. two years of biology in high school - 16%
    5. more than two years of biology in high school 3%

3. I have taken:

    1. no college biology (botany, zoology, physiology) courses 72%
    2. one quarter of college biology - 24%
    3. two quarters of college biology 3%
    4. a year of college biology prior to this course - 1%
    5. more than a year of college biology prior to this course - 0%

4. At MSU I have taken:

    1. less than one year of Natural Science - 14%
    2. one year of Natural Science - 58%
    3. A waiver (by examination) of the Natural Science sequence - 0%
    4. A waiver (by course substitution) of the Natural Science sequence - 14%
    5. No Natural Science course - 14%

5. At MSU I have:

    1. not taken Physical Science 203 - 74%
    2. have taken Physical Science 203 - 20%
    3. have waived Physical Science 203 by examination - 3%
    4. have waived Physical Science 203 by course substitution - 2%
    5. am currently enrolled in Physical Science 203 - 0%

6. I transfered to MSU from another school:

    1. yes - 39%
    2. no - 61%

7. I am repeating Biological Science 202 this term:

   1. yes - 2%
   2. no - 97%

8. Which of the following most accurately describes your attitude toward biological science:

   1. very negative - 2%
   2. negative - 7%
   3. neutral - 32%
   4. positive - 48%
   5. very positive - 10%

9. I expect to spend ____ hours per week studying for this course outside of class:

   1. less than 2 hours per week - 0%
   2. 3 - 5 hours per week - 27%
   3. 6 - 8 hours per week - 55%
   4. 9 - 10 hours per week - 16%
   5. over 10 hours per week - 2%

10. The grade that I realistically expect to receive in this course is:

    1. 1.0 or 1.5 - 0%
    2. 2.0 - 3%
    3. 2.5 - 15%
    4. 3.0 - 50%
    5. 3.5 or 4.0 - 32%

BIOLOGY PREPARATION FOR PROSPECTIVE ELEMENTARY TEACHERS

Presented by Dr. Jean Enochs

Rapporteur's Report

by Dr. Bruce Cheney

Dr. Enochs opened the discussion by providing a brief summary of her paper. In her summary she indicated that it was her view that Biological Science 202 should be:

1) A part of the liberal arts tradition which is to provide non-specialized students with a broad perspective of biology as an academic discipline;

2) Taught in a manner that models the "inquiry" process that is presently advocated for children in the elementary schools;

3) Designed to develop in students an appreciation for the historical, philosophical, and contemporary impact of science on society;

4) Based on an ecological theme which is "in tune" with the current interest in environmental issues;

5) Effectively providing a background for understanding and teaching aspects of human health and disease; and

6) Focused on individual needs of learners, providing options well suited to the academic backgrounds of students.

These features of the course were generally well accepted by the analysis group participants, with the possible exception of the audio-tutorial system as the best means for individualizing instruction and for providing the program options that students might find most challenging.

Dr. Enochs expressed these personal concerns about the course as it now exists:

1) Dissatisfaction with the level of mastery that is commonly achieved by students;

2) Uncertainty about the wisdom of attempting to use teaching methods at the university level that are commonly used in elementary schools;

3) Student reports that the course is too demanding, particularly with respect to time; and

4) Continuing student negativism toward biology as a subject and toward science teaching in general.

A number of participants commented on point number two (2) above. A common remark among the participants was that the first priority ought to be to employ teaching methods suitable for university age students and which will tend to maximize the learning of biology. The belief seemed to be strong that student knowledge of biology -- both its conceptual and its process components -- were of overriding importance. Where appropriate it might be wise to provide a model of science instruction that is desirable in teaching science to children, but methodological objectives are not the primary responsibility of BS 202. Concern for the present lack of integration among the six science courses required for Elementary Education students was expressed. The hope was voiced that in attempting to provide a more integrated program that we don't continue to repeat the errors of the past. In this respect it was pointed out that Dr. Mason, before his retirement in June, 1976, prepared a number of instruments which might be of help in obtaining information about students and their knowledge about and attitudes toward science. Various SMTC staff members have copies of these instruments.

The point was made that in view of the dissatisfaction with student knowledge of biology (Concern number one (1) above) that skill in how to acquire knowledge as it is needed may be the most useful knowledge objective that can realistically be achieved. This comment was related to knowledge of accurate reference materials and to inquiries directed to people and departments here at the university as teachers have occasion for information; it was not a suggestion that students acquire all information by the methods of scientific inquiry. It was stated that the university needs an instrument for assessing the level of biological knowledge which students possess when they enter the science program. There was general support for this notion, although some argument ensued relative to what the university response would be even if we had such knowledge of students' biological "literacy." The absence of some of the traditional AT and "wet lab" experiences in present Natural Science courses was noted. The opinion was offered that the use of audio-tutorial and other modern modes for mass education often leave little room for the wet lab and some of its accompanying exploratory behavior. This suggestion was supported by a few participants; others did not argue the point. It was also suggested that the topical content of the course should reflect as closely as possible to the contemporary social issues. In this case, energy utilization and health science were offered as suggestions.

The question of attitudes toward biology and science teaching was touched on very lightly. There seemed to be a general view that academic achievements of merit would go far in developing favorable attitudes toward science. More prolonged instructor/student interactions on an individual and group basis were also suggested as a means of improving attitudes. It was suggested that "we all" ought to do more to teach for improved attitudes and that we need to employ means for evaluating the attitudes which students hold at the end of our courses.

A number of responses were elicited as a result of Dr. Enochs' proposal to more systematically identify the needs, the abilities, and the affective characteristics of the students in BS 202. It was asked if students today differ in any important respects from students of ten years ago. Are they more dedicated now? Some participants speculated that there is little apparent difference between the two groups of students and that more of the present group should be persuaded to enter other majors because of low commitment to teaching and the scarcity of teaching occupations. All agreed that the teacher's role is too important to allow the unqualified and the uncommitted to occupy it. In reference to the end-point outcomes of the teacher preparation program it was agreed that instructors in science and science education should see the prospective teachers present science lessons to children; that these people could provide the best assistance with and the most pertinent evaluation of the science teaching skills of the students.

Dr. Enochs' proposal to develop alternate educational experiences for students in BS 202 was well accepted by the group. Some members were concerned that the A-T instructional mode, though highly individualized in terms of self pacing, was too mechanical and impersonal. Greater human interaction was sought by this group. The use of teachers in the field as sources of information about what content and processes "should be included" in the course received quite a lot of support, though some expressed reservations about the suitability of asking teachers who, for the most part, do little science teaching to play influential roles in determining appropriate course content. There was general agreement that course content ought to include powerful conceptual themes with high relevance to elementary science curricula and approximately equal emphasis on processes of science which have great generalizability and resistance to obsolescence. The ability to seek answers and to deal with new conceptual ideas as careers evolve was seen as a highly appropriate objective for general education in science -- both in the Natural Science program and in BS 202.

The participants were generally complimentary of the efforts of Dr. Enochs to look at BS 202 objectively and openly. There seemed to be a mood to cooperate in attempting to achieve some integration of science courses and to consider the issues of course content, instructional modes, and student assessment that were raised in this session.

PROBLEM SOLVING AND MATHEMATICS EDUCATION

Keith M. Hamann
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PROBLEM SOLVING AND MATHEMATICS EDUCATION

Dr. Keith M. Hamann

Basic premises for learning and teaching mathematics

1. Learning should be active, not merely passive or receptive.

But time is limited and we cannot expect students to rediscover the whole of mathematics:

- it is a long and difficult task,
- many students will not want to,
- many students will not be able to,
- it is inefficient and unpopular with both teachers and students.

A solution is to try for something less ambitious: let the students "discover" by themselves as much as is feasible under the given circumstances, i.e., aim to perpetuate the type and provide for growth beyond the type.

2. Learning begins with action and perception, proceeds to words and concepts, and should end in desirable mental habits.

The sequence of steps might be

- Presentation of the task (or problem),
- Discussion of the problem,
- Informal approach to the problem, e.g., observation, exploration, pattern formation, examples, ...,
- Formalization of the task.

On Problem Solving: Why?

There is no best way of teaching; there are as many good ways of teaching as there are good teachers. But on one point there is a common view:

"the mere possession of facts is of little value in mathematics"

To know mathematics means to be able to do mathematics, e.g., to use mathematical language, to find the unknown, to use inductive and deductive methods, to check a proof, ... Therefore, to teach mathematics we must give our students an opportunity to do mathematics. One good way of doing mathematics is via the activity of solving problems. (In accepting this statement our responsibility is to ensure that it is reflected in the work and attitude of our students: they must be shown how problems can be approached and helped in developing their skills in supervised practice sessions.)

Two types of problems arise: routine and non-routine.

Routine problems have specific aims and should teach the student to use correctly a particular rule or procedure or definition. They require drill and practice and demand little in the way of any invention or originality. The specific skills developed may:

a. be needed in future studies, vocation and/or examination,

b. help develop desirable mental habits, e.g., orderliness, accuracy, ability to concentrate, ability to handle abstract concepts, ...

Non-routine problems should challenge students' inventiveness and originality, require them to call on previous experience, to sustain an effort, to order their thinking and aim at some more general and higher objective, e.g., implant in the students' minds attitudes and procedures which may be generally useful for solving any kind of problem in any discipline.

The teaching of mathematics in the secondary school should emphasize the general tactics of solving problems, i.e., analyzing, simplifying and generalizing, through a consideration of a wide variety of different problems and different methods. For potential users of mathematics, the ability to solve such problems may be the beginning of the professional attitude that produces a creative contributor to society. For non-users it may be the most useful thing that remains with them from their mathematics studies.

On Problem Solving: What is it? How?

I am concerned here with the development of the general tactics of solving non-routine problems. (It is not to be confused with getting students to solve problems. This is only part of the first and of little use without it.)

How do we develop these skills in our students? The following brief statements will be of great help.

1. Hildebrandt gives 8 stages of problem solving that students might to some extent follow, either consciously or unconsciously;

- Presentation
- Attention
- Observation and Exploration
- Classification
- Further exploration
- Formulation

- Generalization
- Verification and Application

(Hildebrandt: "Mathematical Modes of Thought" in the Growth of Mathematical Ideas: Twenty Fourth Yearbook of NCTM.)

2. Polya sums it up in the following way:

- Understand your problem: distinguish principal parts and try to foresee the result, e.g., try to look for a developing pattern.
- Conceive a plan before you tackle the details. (Polya supports the "working back" procedures strongly.)

What is the picture I see in the contemporary classroom? It is true that there is a vast amount of enrichment material in use: students are playing logic and "thinking" type games and solving a wide variety of mathematical and non-mathematical puzzles and problems but there is strong evidence to believe that

- the game is simply being played for the period set,
- the puzzle is being solved by luck or guess or intuition or by the "bright" member of the group,
- the problem is being "solved" or "discovered" by the bright student or a parent or ....,
- none of the above happen because the students do not know to start and give it up as being "too hard" or because nobody seems interested in helping them,
- some puzzles and problems are solved by methods that are either wrong or are unique and do not allow for generalization. (While there is nothing basically wrong with this latter course. I believe that there is more to it than just an answer.)

In all of the above situations the teachers are not seen as they believe, (quite wrongly), that they should not help in this "individual" or "creative" situation.

We can, (and we must), do better by all students. At the various points in the development, the game (or puzzle or problem) must be:

- introduced and some basic ideas given, (always remembering that too much help is as bad as too little help),
- analyzed for best strategies and/or solutions,
- followed up with other games or puzzles or problems which have slightly higher levels of sophistication but can be understood and developed from the past experiences,

and finally

- opportunities given for students to create their own games or puzzles or problems which may be solved by the class. (Preferably the students' work should be extensions or side developments of the original.)

In doing this the teacher will give the student various strategies and techniques as suggested by Hildebrandt, Polya, and others. The problems used should be of immediate interest and allow for extension and/or generalization. All students can benefit by this study of the tactics of problem solving: the good teacher has a supply of suitable problems for every occasion and every group.

On Problem Solving: Some examples

Problems are needed for all seasons and for all moments. All teachers should have a bank of problems, puzzles, games for use at appropriate times. In addition they should be familiar with a variety of approaches and solutions to these problems.

In what follows some examples of questions I have in my bank along with comments on how I use them are given.

"Thinking Clearly" type questions

- These are not all mathematical questions but they require careful reading, (and re-reading), and a consideration and rejection of possible solutions.
- Avoid trick questions, i.e., those that distort the logic and/or mathematics.
- An easy way to build your bank is to ask students to find one to give to the class.
- Encourage discussion and extensions to the problems.
- Expect a contribution to the problem (even if it leads nowhere) from every student. Do not let the "bright" students dominate.

1. Two boys are standing a metre apart, one facing North and the other facing South. How could they see one another without turning around?
2. Two mothers and two daughters went to the pictures. There were only 3 seats available and yet they all got a seat. How was this possible?
3. If Simon is older than Rick, but younger than Sue, who is the youngest?
4. If half the links in a chain will take a strain of 2 tonnes and the other half will take a strain of 4 tonnes, what strain will the whole chain take?
5. If 5 girls can thread 5 needles in 5 seconds, how many girls would be needed to thread 50 needles in 50 seconds?
6. Which two odd numbers, when multiplied together give 17 as the answer?

7. If John could not lie and Ron could not tell the truth, and one of them said, "He says he is Ron", which one spoke?

8. A clock takes 2 seconds to strike two o'clock. How long does it take to strike three o'clock?

9. Rod, Glen, Mark and Peter go out orienteering. When Rod is north of Glen, and Mark is east of Rod, and Peter is south of Mark, who is east of Glen?

10. In a car park there are 11 motor vehicles comprising motor cars and motor bikes. If there are 36 wheels how many cars are in the park?
(Hint: how many wheels would there be if there were say 7 cars and 4 bikes?)

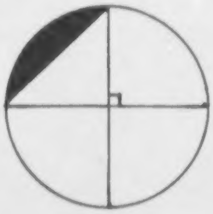
"Structured" Problems

- These are extension or application problems related to the current mathematics being studied.
- Most modern texts have a number of such problems.
- These problems must be approached in a more logical and structured way.
- In these examples the difficulty order is very different. They are meant merely of examples of structured problems which could be given in conjunction with the appropriate course work.

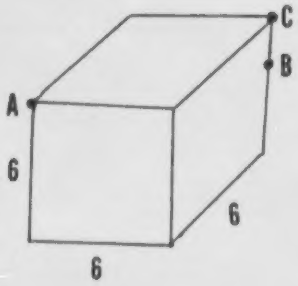
1. Said Linda, "If I had one of your horses, I'd have as many as you".
Said Vicki, "If I had one of yours, I'd have twice as many as you".
How many horses did each girl have?

2. What is Jack's present age if he is now three times as old as when he was half as old as he was five years ago?

3. What fraction of the total area of the circle is the area of the shaded segment?



4. An ant is located at the vertex A of a cube of side 6 cm. He crawls to B, 2 cm. from C, by the shortest route possible. How far does he crawl?



5. Construct a triangle given its three medians.

6. (i) Three lighthouses are visible from a ship; their positions on the map are known and the angles between the rays of light from them have been measured. Plot the position of the ship on the map.

   (ii) The time at which the sound of an enemy gun is heard has been exactly noted at three listening posts A, B and C. On the basis of these data plot the position X of the enemy gun.
   Regard the velocity of sound as known.
   Explain the analogy with, and the difference from, the problem of the three lighthouses.

7. (i) One pipe fills a tank in 15 minutes, another can fill it in 20 minutes and a third in 30 minutes. With all three pipes open, how long will it take to fill the empty tank?

   (ii) Tom can do a job in 3 hours, Dick can do the same job in 4 hours and Harry in 6 hours. How long would it take if they worked together?

   (iii) Three cars set out on a journey. Each car has an average fuel consumption of 25 miles per gallon and each tank holds 18 gallons. If each car is allowed only a single tank full of fuel, how far can 3 people travel? (They start with full tanks but are allowed to transfer fuel from car to car and leave cars behind.)

   (iv) A rocket ship is to go from Earth to a planet P. It is a 5 day trip, but the rocket holds only enough fuel for 3 days flight. Fuel stations A, B and C are 1, 2 and 3 days flight from Earth respectively. The fuel stations are empty but Earth has an unlimited supply of fuel. The rocketship can leave fuel at stations A, B, and C. What is the minimum number of days required to reach planet P from Earth?

8. Which is the best fit -- a square bolt in a round hole or a round bolt in a square hole?
Give reasons for your answer.

"Pattern Problems"

- These problems allow for extension and/or generalization.
- The following stages of development are seen:

Introductory stage: The teacher leads and directs the presentation, discussion, investigations and solution of a base problem.

Extension stage: Students use the experience and knowledge gained from the base problem to generalize the problem or solve a new, (but related), problem.

Design stage: Students create and design and present a solution to a similar problem.

Consolidation stage: The teacher reviews the problem series and the students have

- a useful and relevant body of knowledge,
- a technique for approaching problems.

We would all agree that a worthy aim is to make students self-reliant and autonomous. But it must be recognized that this grows out of an awareness by the students of

- what skills are at their disposal,
- how and where these skills can be used,
- how to use new knowledge and skills to acquire further knowledge and skills.

In the past "conventional" teaching often was concerned only with the first factor, i.e., the development of skills. The present "liberal progressive" teaching is often only concerned with developing self-reliance and independence and the acquisition of knowledge and skills is reduced to a minimum. I would suggest that this has exchanged one form of restriction for a worse. In the latter situation neither the student nor the teacher is in control and the best resources of each are lost. (Note: No attempt has been made to grade these problems. They are presented only as examples of what might be done.)

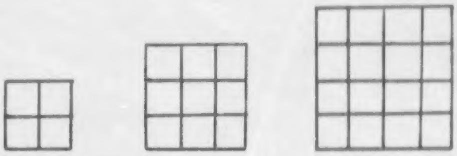
1. The Counterfeit Coins Problems

   Base problem:
   We are given 27 coins of the same denomination: we know that one of them is counterfeit and that it is lighter than the others. Locate the counterfeit coin by using three weighings on a balance.

   Extension problems:
   What is the least number of weighings required to find the one light counterfeit coin in a group of:
   (a) 40 coins,
   (b) 80 coins,
   (c) 81 coins,
   (d) 500 coins,
   (e) n coins?

   For experts
   Consider the problem if the counterfeit coin is simply a different weight, i.e., it may be lighter or heavier.

2. The Lattice Problems
   Base problem: How many squares in each of the following figures?



Extension problems

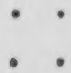
a. Extend the above.

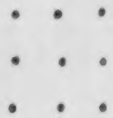
b. Generalize to n x n square.

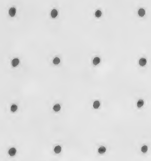
c. What about triangles? (But be careful. See below)

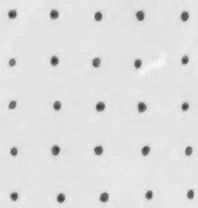
For experts

1. Given the lattice points as shown in the figures below:





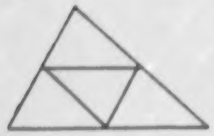


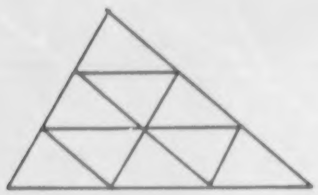


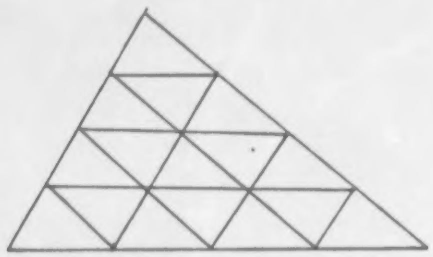
Using each lattice point as a vertex how many squares can be formed in each pattern?

Generalize your result for the n x n lattice.

2. Try triangles. How many triangles in each of the following figures?







Extend the above.

3. The Traveller and the Gold Chain

Base Problem

A traveller having no money, but owning a gold chain having seven links, is accepted at a hotel on the condition that he pay one link per day for his stay. If the traveller is to pay daily, but may take change in the form of links previously paid, and if he remains 7 days, what is the least number of links that must be cut from the chain? (Note: A link may be taken from any part of the chain.)

Extensions

What is the least number of links that must be disengaged from a chain of 2000 links in order that any specified number of links, from 1 to 2000, may be gathered together from the parts of the chain thus formed?

4. The Digits Problems

Base Problem

Write down any 3 digit number in which the hundred's digit is larger than the units digit. Reverse the digits, then subtract this number from the original number. Reverse the digits in the answer and add this new number to the first difference. What answer did you get?
Repeat the process with another 3 digit number.
Prove this result.

Extension Problems

Try 4, 5, 6, ... digit numbers until your patience runs out.

5. The Monkey and the Five Sailors

Five sailors and a monkey are on an island and the sailors have collected a heap of nuts. Deciding to divide the nuts equally the next day, they retire. During the night one sailor arises, separates the nuts into 5 equal parts, having one nut left, which he gives to the monkey. He hides one part, pushes the other piles together and returns to his sleep. He is followed in turn by the other 4 sailors, each of whom takes one-fifth of the nuts and gives the extra one to the monkey. Next morning, the remaining nuts are divided equally, with one left-over nut being given to the monkey.
What is the least number of nuts they could have had?

In this case the above problem is presented first. But clearly it is complex. One approach is to get students to suggest a starting point, i.e., a base problem.

Base problem

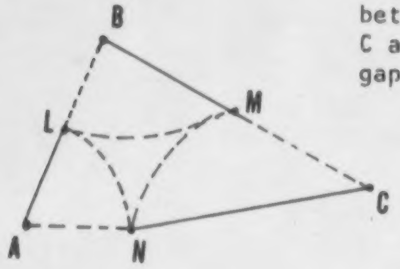
Suppose 2 sailors and a monkey. How many nuts could have been collected and satisfy the conditions?
Approaches may be via:
pattern formation: $2^3 - 1$ or in general $k.\ 2^3 - 1$
or algebra: $n - 15 = 8k$
In both cases k can be any integer. Try it.
This can then be extended to 3, 4, 5 sailors.

6. Sawyer's Bear Problems

This series of problems concern a man who is troubled by bears and builds a series of gates to keep them out.

Problem 1:

There are three posts A, B and C. The distances between them are as shown in the diagram. The man wants to mount one gate on each post. The gates are shown by AL, BM and CN. (Note: the gates do not keep anything out but if a bear approaches the gap between A and B, or B and C, or C and A the gates will allow the gap to be closed).



The problem is: if all the gates meet neatly without overlap, how big should each be?
(Try with other triangles, e.g. 3,4,5; 20,80,90; 11,12,21;...)

Problem 2:

Try the Bears problem with four posts:

a. with sides 10, 12, 10, 16 units respectively,
b. with sides 14, 12, 14, 16 units respectively,
c. with sides a, b, c, d units respectively.
Generalize your results.

Problem 3:

Try the Bears problem with five posts:

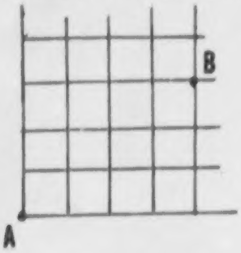
a. with sides 10, 12, 8, 6, 4 units respectively,
b. with sides 10, 10, 10, 10, 8 units respectively,
c. with sides 10, 11, 12, 13, 14 units respectively,
d. with sides a, b, c, d, e units respectively.
Generalize your results.

Problem 4:

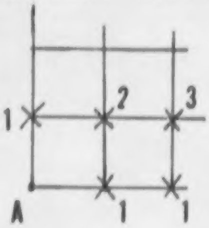
Over to you.

8. Another Pascal Triangle Problem

The figure represents a "street map" of a large town. Starting at A, how many "sensible", i.e. shortest, ways are there to reach any other intersection like say B?



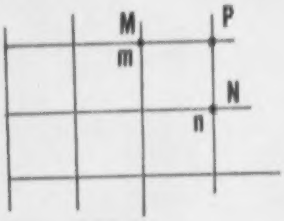
Hint: Start in a systematic way by finding the number of sensible ways of getting to each intersection. Write this number near the intersection, e.g.



Answer the following questions:

(i) Can you see Pascal's numbers in the pattern?

(ii) In the diagram below there are m ways to get to M and N ways to get to N. How many ways are there of getting to P?



(iii) Justify or explain these results in words.

Extra for Experts

(iv) Explain these results in terms of combinations. (Hint: let B have co-ordinates (x,y) - how many unit steps have to be made regardless of path taken?)

(v) A(o,o) B(9,11). Find probability that if a random path is chosen from A to B it goes through
a. (3,7), b. (2,5).

(vi) A(o,o), B(10,10). If two paths from A to B are chosen at random find the probability that they intersect.

(vii) A(o,o), B(10,10). If Alf walks randomly from A to B while Bob walks randomly from B to A what is the probability that they will meet at some intersection? (Note: they start at the same time, walk at the same pace.)

(viii) A(o,o) B(x,y) Generalize the problems (vi) and (vii).

9. The Birthday Problems

1. What is the least number of persons required if the probability exceeds 1/2 that two or more of them have
   (i) their birthdays in the same month of the year.
   (ii) the same birthday? (Year of birth need not match.)

2. You want to find someone whose birthday matches yours. What is the least number of strangers whose birthdays you need to ask about to have a 50 - 50 chance?

3. Labor laws in Paradise require factory owners to give every worker a holiday whenever one of them has a birthday and to hire without discrimination on grounds of birthdays. Except for these holidays they work a 365 day year. The owners want to maximize the expected total number of may days worked per year in a factory. How many workers do factories have in Paradise?

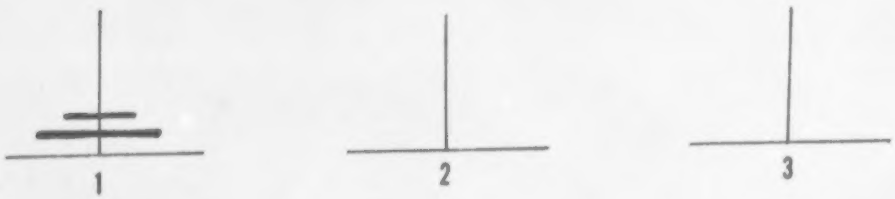
These problems can be illustrated nicely by a computer program and print-out. For example:

```
1.  A = 1
    For N = 2 to 60
    X = (366-N)/365
    A = A * X
    P = 1 - A
    Print N, P
    Next N
```

```
3.  For N = 20 to 360 step 20
    H = 365 * N * (364/365)↑ N
    Print N, H
    Next N
    For I = 361 to 370
    T = 365 * I * (364/365) ↑ I
    Print I, T
    Next I
```

10. Tower of Hanoi problem

(i) Two discs rest on pin 1. What is the minimum number of steps in which you can move the 2 discs to either pin 2 or pin 3? (A step is defined to be the movement of one disc from one pin to another. You can remove only 1 disc at a time and a larger disc can never rest on top of a smaller disc.)



(ii) Repeat part (i) if there are
a., 3 discs resting on pin 1,

b. 4 discs resting on pin 1,

c. 5 discs resting on pin 1,
d. 8 discs resting on pin 1,
e. n discs resting on pin 1.

(iii) If X is the number of moves required to shift a pile of n discs and Y is the number of moves required to shift a pile of (n + 1) discs explain why

$$Y = 2X + 1$$

(Hint: start with n = 2.)

PROBLEM SOLVING IN MATH

Presented by Dr. Keith Hamann

Rapporteur's Report

by Dr. Wm. Fitzgerald

The author began the session by sharing with the group his motivations for writing the paper. He stated that as a teacher he had always been interested in getting students to solve problems and found students to remember non-routine problems longer than routine problems. Further, in his regular duties of observing teachers he frequently sees the introduction of puzzles, games and problems in a somewhat aimless fashion with no discussion of strategies the students might use. To counter this, he suggests the use of base problems as illustrated in his paper. These problems serve as a lead off point to a family of related problems and finally to a generalization of a solution. It was suggested that the collection of base problems serve as an example of the "half-product curriculum" as described by Kilpatrick and cited by Shulman.

Oakland County Schools has been involved in the Problem Solving Project which was funded by NSF and based at Indiana University. In that project attempts were made to identify problem solving strategies which can be taught to children but work on the project has ceased due to termination of funds.

The workshop group attempted to ascertain the reasons why teachers seem so hesitant to encourage problem solving activities in their classroom. The following are some suggestions:

a) Many teachers view mathematics as computation. When children are using manipulative materials they are not doing mathematics.

b) Teachers feel peer pressure to keep classrooms quiet and to not use "gimmicks."

c) Teachers don't see a wide developmental sequence in the development of mathematical ideas.

d) They don't understand how to work with math groups as they do reading groups.

e) The undergraduate preparation is hopelessly unrealistic in assisting a new teacher to be prepared to teach well. Until recently, nearly all perspective teachers learned their mathematics in large groups of 300 or more.

Some hopeful signs are appearing:

a) In South Australia, new teachers are given an 80% load their first year and receive additional help from an administrator employed for that purpose. Also, inservice programs usually involve an entire school faculty and the total curriculum.

b) In Michigan we already have a Professional Growth Center in Detroit with four more soon to be funded by the M.D.E. Oakland County is planning to fund their own center soon.

c) The State objectives are beginning to contain a larger number of problem solving objectives with additional suggestions which might encourage more teachers to be sensitive to the need for problem solving experiences.

Finally, there was a strong need expressed for more research and more cumulative reporting of research findings which will be significant to the teacher. The SMTC may have the resources to accumulate research results speaking to specific concerns of classroom teachers and disseminate those findings in some helpful way.

THE PAST AND FUTURE OF ENERGY EDUCATION AT THE SCIENCE AND MATHEMATICS TEACHING CENTER

Martin Hetherington
Michigan State University

THE PAST AND FUTURE OF ENERGY EDUCATION AT THE SCIENCE AND MATHEMATICS TEACHING CENTER

By Dr. Martin Hetherington

Energy problems in this country are widespread and of great concern. This discussion deals with the Science and Mathematics Teaching Center's past and intended future contributions to a partial remedy of these problems - Energy Education.

The Past

The Science and Mathematics Teaching Center (S.M.T.C.) has been involved in the development of energy education for the last eight years. The initial incursion into energy education began in the 1969-70 academic year when Wayne Taylor together with Glenn Berkheimer and Richard McLeod formed an energy education review team to work with representatives of utility companies from around the nation in order to review and revise energy education materials for classroom use. At this time it was recognized that the concepts of energy must be introduced into the school classroom. The following year the S.M.T.C. sponsored the "This Atomic World" program in conjunction with the Consumers Power and Detroit Edison Companies. This program continued through 1972, with Consumers Power support, and visited nearly 300 schools throughout Michigan. Recognizing the need for improved teacher understanding of energy education the S.M.T.C. with the support of Detroit Edison and the assistance of Carl Berger, developed an inservice course in energy for teachers.

1972 also marked the beginning of the S.M.T.C.'s involvement with a sophisticated and potentially powerful tool in energy education; The Energy Environment Game. Glenn Berkheimer, Bob Brandou, Richard McLeod and myself met with the Game's developer, Ray Montgomery of Creative Studies, Inc., to modify the Game for classroom use. In the Fall of 1972 Richard McLeod and graduate student David May piloted the classroom version of the game and tested a workshop model with inservice teachers. During the next two years SMTC teams (consisting of myself, Glenn Berkheimer, and graduate students Fred Finley, Dennis Dunmire, and John Fogl), with the sponsorship of Consumers Power, conducted over 30 workshops for Michigan teachers. As a result of this effort more than 600 Energy-Environment Games have been distributed in Michigan.

Although energy problems existed prior to the 1973 Arab Oil Boycott, the general public had little interest in energy education at that time. Recognizing future needs, Bob Brandou, former SMTC Director, organized a second energy education materials and media review group with the Edison Electric Institute, even though energy education was not widely taught in the schools. OPEC's actions changed this climate and began the current era of energy concern and awareness.

On August 7, 1974 the Michigan Energy and Resource Research Association (MERRA) was formed as a consortium of Universities, State agencies, and industries in the State of Michigan. MERRA commissioned an Energy Education Committee, of which I was appointed chairman, to study the energy education activities of Michigan's institutions of higher education. A report on these activities was released in the winter of 1977.

The SMTC became involved with the Bolton Institute Energy Conservation Workshop project in 1975. With the cooperation of the Center of Environmental Quality and the financial support of the Michigan Science Teachers Association, the Michigan Environmental Education Association, 4-H, Pontiac Schools, Lansing Schools, and Michigan Technological University, the Bolton Institute Workshops were conducted around the state. Similar energy workshops were also conducted in Alabama, Colorado, Georgia, and New York.

Under Joe Janeti's direction the Michigan version of the Bolton Institute Energy Workshop plan has evolved into Project ENTROPY, part of which is currently supported and housed by the SMTC.

1976 was an active year for the SMTC in Energy Education. In the early part of the year the Center's faculty and staff conducted a feasibility study on the development of an Energy Education Curriculum for grades K-12 under a contract from the Federal Energy Administration. The resultant Curriculum Model, original in many concepts, was reviewed and evaluated by a committee of energy educators including John Fowler, John Jones, Peter Gladhart, Jonathan Wert, and Barry Jameson. Also during this time the SMTC was represented at the Educational Testing Services hearings on energy education in Chicago and the Detroit hearing on the Energy Research Development Administrations energy plan conducted by the Council on Environmental Quality.

Currently the Science and Mathematics Teaching Center is continuing its efforts in energy education in three areas; development of State Energy Education proposals in cooperation with the State Department of Education and the Michigan Energy Administration, development of a multiple-state energy education proposal, and on the evolution of an energy-extension model with the cooperation of other Departments and Colleges at MSU.

The Future (Directions for Energy Education)

President Carter's April 20th address to the American public on the "Energy Crisis" once again focused attention on world and national energy problems. Subsequent public opinion polls and 'man-in-the-street' news interviews uncovered a considerable amount of skepticism on the credibility of public agencies and officials, and private industries concerning the energy issue. The American public, it would seem, believes it is being fed distorted information, half truths and perhaps lies to substantiate the claims of industries with vested interests or garner support for self-serving politicians. "No energy crisis may in fact exist, it may only be the result of information fabricated and manipulated for selfish ends." The SMTC faculty believes that in order to partially reestablish institutional credibility, the public must receive reliable, straight-forward information from public agencies. Any energy information or study should carry documentation indicating the method of data collection, the agencies, industries, or individuals responsible for the data collection and compilation, and the parties responsible for funding the study. The purpose of the study should also be clearly explained--is it refuting an old study or presenting new information? Although such suggestions would not eliminate inconsistencies between studies, their implementation would allow the public to know whose 'Truths' they're being confronted with and the informational basis.

In order to make intelligent decisions on energy matter the general public must be, in some sense, scientifically literate. Today, even if presented with undistorted factual information many people cannot deal with that information responsibly in order to make reasonable decisions. Technical information threatens or is a source of frustration to many and is religiously avoided. It is here, with the majority of the American public groping their way within a complex technological society, that energy educators must become more active. The list of topics that the American consumer must become conversant with is extensive; fuels, alternative energy sources, energy transmission, energy production, energy transformation (chemical to mechanical, etc.), economics of energy, basic physical laws concerning energy (2nd law of thermodynamics, etc.), energy technologies and their advantages and limitations,... In addition the concept of 'trade-offs' must also be introduced as an essential part of decision making. Dealing with any complex problem requires more than a simple yes or no, oil or coal, solar or nuclear decision but rather a complex integration of information and reason to produce an acceptable compromise between individuals, life-styles, profit and loss--all the myriad factors of modern life. Understanding the concept of trade-offs helps strengthen this mode of reasoning.

The last area in which I feel energy educators should involve themselves is in the Philosophy of Energy Utilization and Consumption. The quality of life in this country is deemed by many to be rapidly declining, faster perhaps than our energy usage is increasing. Energy educators must address themselves to the question of quality, not just to energy development and maintenance. Perhaps questions must be addressed to basic assumptions on life and lifestyle; questions which may be painful, but absolutely necessary for those living on a finite planet.

The Science and Mathematics Teaching Center intends to be in the forefront with those concerned educators, scientists, and citizens, helping the Nation face the inevitable energy problems in the years ahead. The SMTC recognizes the fact that energy problems are only as severe as the educational inadequacies of the population which must face them. Comprehensive energy education is what we must concentrate on.

THE PAST AND FUTURE OF ENERGY EDUCATION AT THE SCIENCE AND MATHEMATICS TEACHING CENTER

Presented by Dr. Martin Hetherington

Rapporteur's Report
by Dr. Larry Schafer

Introduction

The group members did not critically analyze the paper nor did they discuss the priority of the various suggested areas of involvement. They did, however, discuss the needs for energy education, the tasks or projects which the Center might undertake, and the means of accomplishing those tasks. Those suggestions, which the rapporteur has taken great liberty to embellish, are summarized below. Any comments regarding priority are those of the rapporteur.

Suggestions and Comments

1) Develop and implement a method of helping people in schools, businesses, and governmental agencies become aware of the need for energy education.

Comments:

a) Since interest in and support of energy education arises out of an awareness of need, this task of awareness education must command high priority.

b) Through awareness education, people should understand that the issues, problems, and solutions relative to energy are multi-dimensional and thus require consideration of social, cultural, ethical, and technological elements.

2) Design and develop a resource center for energy education. This resource facility could serve as:

a) a Teacher Center which would provide teachers with the means of developing materials for use in their classrooms. The Teacher Center would not only provide teachers with a rich source of ideas for curriculum development but would, as well, provide teachers with guidance on how to select, adapt, create, sequence, implement, and use curriculum materials. Workshops and consulting services would be offered by the Teacher Center personnel and the Center would coordinate the activities of "energy teams," perhaps consisting of experts from the university, businesses, and the public schools.

b) a Clearinghouse for technical reports on energy. This Clearinghouse should, in addition to compiling and organizing reports, provide evaluations of reports and should, as well, provide guidelines to help individuals make their own evaluations of the reports.

Comment:

This resource center should be developed concurrent with efforts to generate awareness of need for energy education and therefore is of high priority. To encourage teachers to contribute teaching ideas to the Center's collection, teachers might repay their use of the Center with the novel materials and ideas they develop.

3) Create and adapt energy education materials (activities, tasks, etc.) for use at various levels of education (K-adult).

Comments:

a) With teachers spending increasingly more time on the basic non-science subjects and with school budgets diminishing, the development of a complete and sequential K-12 energy curriculum would, at this time, seem inappropriate. There would neither be money to purchase the program nor time to teach it. Given these conditions and the notion that teachers are most enthusiastic about teaching that which they have developed, the energy education materials created might take the form of "half-products" (i.e., exciting ideas and activities which must be more fully developed and adapted by teachers). To insure that the "half-products" are appropriately used, there must be a mechanism for helping teachers develop-adapt, sequence, and implement the activities and materials generated from the "half-products."

b) The instructional activities which are developed must be interdisciplinary. The issues and problems associated with energy are not merely technical or scientific. The social, cultural, political, and economic ramifications of energy production and use are of paramount importance and therefore must be part of energy education.

c) The instructional materials must include value clarification and construction activities which focus on the ethical and moral issues associated with energy. Both young and old people must form their own belief systems for the ethical and moral judgments regarding such issues as waste, conservation, and priorities of energy use. Also, people of all ages must evaluate the quality of their lifestyles in light of energy demands and use. Perhaps, quality lifestyles need not require inordinate amounts of energy; certainly they demand minimum waste.

d) Since one way to change adults' behaviors, beliefs, and knowledge is through the changed behaviors, beliefs, and knowledge of their children, the educational materials must include practical suggestions for intelligent energy use and conservation in homes. Such concrete action in homes would not only serve to educate adults, but would, as well, further enhance children and adults' committment to wise energy use. Also, the idea that "action gives rise to committment," should be applied to school as well as home environments (school energy policy and practice).

e) The curriculum materials must insure that learners acquire knowledge of those technical terms which are needed for intelligent and evaluative consumption of energy information.

f) The instructional materials should help learners become future oriented. Given that changes in the availability and use of energy may drastically influence the environmental, social, cultural, and economic fabrics of peoples' lives, people must consider the alternative futures which would result from various courses of action, must examine those futures to determine which are most desirable, and then must create and follow plans of action which will make more probable the existence of the desired futures. Surely young people will be unable to fully grasp and deal with the immense complexities involved in determining alternative futures. Nevertheless, exposure to future education would hopefully develop in students the tendency to be future oriented and hence be deterministic rather than fatalistic.

g) Rather than develop entirely new energy programs for schools, energy activities and instruction could be added to existing science and social science curricula. For example, materials could be produced which provide teachers with the activities and methods necessary for getting more energy related instruction into the SCIS program.

h) To avoid the unnecessary and wasteful proliferation of instructional materials, a mechanism must be developed to determine the energy related skills, knowledge, and attitudes which are worth teaching. Prime consideration should be given to determining the skills, knowledge, and attitudes necessary for responsible citizenship and survival. Those elements of a more academic nature should be given secondary consideration.

4. Develop and implement a cooperative extension model for energy education. Perhaps this would be the overall model which would subsume the Teacher Center, Clearinghouse, and curriculum development activities already mentioned.

5. Design, perform, and synthesize research which facilitates energy education. Perhaps one of the first tasks of such research would be to identify the appropriate matches between the characteristics of learners and the elements of energy instruction.

6. Organize and coordinate a multi-state consortium for energy education.

Comments:

The task is too great and the time too short for any one organization to make the necessary advances in energy education. A consortium of organizations which specialize in the development of various components of energy education and then which freely share their products, materials, and expertise will likely produce the greatest impact on energy education. Such a consortium must be carefully organized and coordinated to insure maximum cooperation, productivity, and efficiency.

AN EXPERIMENTAL TEACHER TRAINING PROGRAM IN MATHEMATICS

John Masterson
Michigan State University

AN EXPERIMENTAL TEACHER TRAINING PROGRAM IN MATHEMATICS

Dr. John Masterson

1. Introduction: The Teacher-Training Program as an Artifact

A renaissance in the field of research in teaching, as it has been aptly called by Shulman (7), articulated anew within the framework of the information processing paradigm, represents a significant change in focus of contemporary educational research.

The hegemony of theories framed in the language of physical science (be they behavioral, cognitive or developmental) and the experimental modes that give them meaning (be they pigeon behavior, case study of children or large population statistical studies) has diminished with the emergence of new kinds of questions asked in a new kind of language and demanding new modes of investigation.

The emphasis of these questions has changed from the general to the particular, to use a word extensively developed and given meaning by Schwab (4: p.496); from reliance on theory to acceptance of the results of careful observation as eloquently but simply put by Cronback:

> "Scientific discipline is what we uniquely add to the time-honored ways of studying man. Too narrow an identification with science, however, has fixed our eyes upon an inappropriate goal. The goal of our work, I have argued here, is not to amass generalizations atop which a theoretical tower can someday be erected (cf. Scriven, 1959b, p. 471). The special task of the social scientist in each generation is to pin down the contemporary facts" (1:, p. 126).

Of the most specific concern in this paper, the research setting itself has changed: from the laboratory where variables are usually easier to control, to the complex interactive environment of the classroom. Rephrasing a distinction made by Shulman (6), we might characterize this change as a desire to correct an imbalance of the past in the natural tension between internal and external validity. Put more specifically by McKeachie:

> "Other problems (in research) have simply derived from failure to take account of important variables controlled in laboratory situations but interacting with independent variables in natural educational settings." (3:, p.10)

You might reasonably be wondering at this point what the above discussion of research has to do with the development of a teacher training program in mathematics. With the help of Herbert Simon, I am beginning to see instructional program development as perhaps a most important kind of research: part of what we might call normative research.

Indeed, research is a respected scholarly endeavor in which we engage to search for truth and for which the university rewards us. I do not question this here. Instructional Program development on the other hand, is usually a seat-of-the-pants operation and only tangentially related to research in the field. We think we know how it ought to go and we do it. No formal disciplined structure exists to inform our programmatic decisions and the university has not put a premium on time spent in such endeavor. (The specific program I will describe later is no exception to this mode of operation. We "know in our hearts" its the best way to prepare teachers.)

It is with no small sense of delight, then, that one who is interested in program development, encounters Simons: The Science of the Artificial (5). For the instructional program is an artifact in Simon's strict sense of the word and its proper design can be explored in richer depth through Simon's concept of a "Science of Design":

> "The peculiar properties of the artifact lie on the interface between the natural laws within it and the natural laws without. What can we say about it? What is there to study besides the boundary sciences - those that govern the means and the task environment?
>
> The artificial world is centered precisely on this interface between the inner and outer environments; it is concerned with attaining goals by adapting the former to the latter. The proper study of those who are concerned with the artificial is the way in which that adaption of means to environments is brought about - and central to that is the process of design itself. The professional schools will reassume their professional responsibilities just to the degree that they can discover a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process." (5): p. 57-58)

As it applies to the present state of the art of designing teacher training in mathematics (and probably most other fields), the above quote is rather sobering.

If the inner environment of the program for training teachers is defined in terms of its present component courses, fixed by the accepted structures of the profession and the university, and the outer environment in terms of its real use to the teacher who will be working in the classroom, then a reasonable interface hardly exists.

One merely needs to examine the usual situation. Separate courses in mathematics, methods and practice, are taught at separate times by instructors whose expertise seldom extends over either of the other two areas. This characterizes the normal training to teach mathematics.

But, what does contemporary research tell us about the teaching of mathematics in the classroom? It tells us that it is a confusing process with content, methods, psychology, management and many other skills being called upon to operate in complex and interrelated ways.

It is to this dichotomy of means and ends that our experimental teacher-training program addresses itself.

2. Description of the Program

This experimental program was initiated several years ago, first as a vehicle for TTT and Teacher Corp and then as an independent alternative to the required mathematics and methods courses. The independent course has developed through several stages and it is only the latter ones I will describe here. It consists of a two-term sequence in which the mathematics (MTH 201) and methods (ED 325E) are completely integrated with an additional one hour field study component added - an hour supervised teaching session with one or several children at Red Cedar School in East Lansing. At the penutimate stage the course was team-taught - one person from the Department of Mathematics, the other from the College of Education. Since many of us are qualified to teach both courses, it is now taught by a single person. (Mathematics credit is given one semester and methods credit the next).

Most significantly, in the last stage, the second term service component has been completely replaced by the entire four hours of class being taught in the Red Cedar School. Rather than working in the mathematics laboratory at Red Cedar for one arranged hour, our students have been matched in pairs with a group of four or five children doing closely related work in an IPI program.

Our teacher-trainees, then, are responsible (under supervision) for providing the core mathematics instruction in a real classroom setting. The specific assignment given to our students demands that they infuse into the low-level skill orientation of the IPI program the concept-

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centered, concrete-based methods of our course. It is no simple task.

The course itself is organized into units similar to other such programs, the University of Indiana program in particular: units on measurement, classification and counting, numeration, whole numbers, fractions, geometry-topology, probability-statistics.

Each unit is developed from the following points of view.

(1) Mathematics content

(2) Methods

(3) Teaching experience

(4) Cognitive theory

I will illustrate this with an example: The unit on classification and counting.

(1) Using attribute blocks, the students are introduced to set concepts, one-to-one correspondence, cardinality of finite and infinite sets, etc. They are expected to be able to understand these concepts both concretely (with reference to manipulatives) and abstractly ($A \cup B$, $A \cap B$ and so on).

(2) Concurrently with understanding the mathematics, and with the use of the attribute games, the students develop sequences of classification tasks which will prepare the children to discriminate sets, count, develop a sense of "greater than", "less than", and so on. These ideas are further developed with reference to other more common concrete objects like buttons, toys, trading cards.

(3) Each student then plans a counting or classification task based in some concrete device and trys it out during their hour of school experience.

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(4) With the developmental psychology of Piaget as a basis, (introduced through one required book and several films) the students examine the value of the concrete experiences in terms of the childs developmental stage, ability to conserve numbers and so on. Also, the mathematical concept of one-to-one correspondence is related to its psychological counterpart: matching concrete objects and word symbols - the beginning of meaningful counting.

In the second semester, as the course is now designed, (3) above does not fit so neatly into the same time frame as do (1), (2) and (4), since the immediate needs of the children at Red Cedar determine what will be done, and our students merely draw upon the materials developed the previous term.

3. Potentialities

The most significant product of the course so far is a myriad of confusing questions and contradictions - most of them conflicts between how we would like to operate in the school room and how we are able to operate. I might teach in our class, for example, a method of introducing numeration concepts through cuisenaire rods, all well grounded in the theory of Piaget. But when my students bring these methods into the school room, they often find that the agenda has changed. What I presented to them as a neat, logical and reasonably antiseptic way of introducing a key mathematical concept loses something in the translation. Some of the kids want to just play with the rods. Others prefer working in their workbooks (they've been doing it for years). For one or two, the rod is a new weapon. Some actually do what was expected. In short, the total result is often disappointing.

So we return to Herbert Simon and find that things are not so bleak:

for these are the expected results when one first arrives in the right theater - the one where the action is. Indeed, if we see the teacher-training program as an artifact, its inner environment defined from the university, its outer from the school room as we have detailed previously, the program which I have described creates the potential for a meaningful interface. We may have hardly yet begun to design a curriculum which adapts to its goals - the complex, illusive goals of the classroom - but we have at least the vital opportunity to begin asking the important questions in this arena in which the inner and outer environments actually meet.

Specific questions have not yet been articulated as we who teach this program have spent most of our energy in bending the conservative compartmentalized structures of a university to keep our integrated program alive. I would like to close, however, with some specific directions for research which a program such as this suggests:

* A study of the interaction of different manipulative devices to teach the same concept.
* The differential effects on children's learning, of various balances in our course of content, methods and theory.
* The faithfulness of translations to the school room of various of our "methods" as taught in the university classroom.
* The correlation between mathematical ability, and/or methods ability, as measured by university classroom measures, and the actual ability to effectively teach as measured in the school experience.

* The creation of some parameters for measuring the goal effectiveness of teacher training programs.

I close with David Hawkins support of our efforts though he does not know they exist:

> "If my emphasis is correct, then these two things, the art of teaching and the fruitful penetration of subject matter, should never be separated. Neither can grow without the other. Yet in the education of teachers, preservice and inservice, we mostly do separate them and growth is mostly stopped.
>
> The art can only flourish as teachers see children learning in relation to the big, exciting world around them, and as teachers can reconstruct--unfold--the traditions of knowledge to make them initially accessible, to make them support children's own native quest."((2): p. 7)

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AN EXPERIMENTAL TEACHER TRAINING PROGRAM IN MATHEMATICS

Presented by Dr. John Masterson

Rapporteur's Report

by Ms. Janet Shroyer

The discussion sessions on Masterson's paper found the participants in agreement that there was a lack of attention to what John referred to as the "interface" between the curriculum taught to teacher trainees and the classrooms in which they are expected to implement what they have been taught. The expectation that teachers will be able to translate the smorgasbord of ideas from their college courses into their daily mathematics instruction is no longer tenable. There is a reality of the milieu in which teachers operate which influences and constrains teachers in ways that we simply do not fully understand and, therefore, have not yet been able to combat.

How then do we improve upon our understanding of this phenomenon and provide training experiences designed to ease the transition from the college environment to the classrooms? One approach is to conduct a program such as Masterson has described and in so doing plan to examine two important questions:

1) What can and do the teacher trainers learn by watching our trainees work?

2) What can we as teacher trainers learn by watching our trainees work?

The need to explore these questions is simple. We as mathematics educators do not, as our students expect, have all the answers. Therefore, information derived from addressing these two general questions would improve our understanding of the problems of the interface.

We might begin by learning more about the constraints that exist and how they operate on teachers and teacher trainees. In what ways are the teachers actually constrained by their environments, including their students, and in what ways do they restrict themselves? For example it seems as though teachers view the use of manipulatives only as an aid with which to introduce content but not something worth sustaining. That is, they see the activities with manipulatives as enabling objectives, not as objectives in their own right. How do teachers' conceptions of the use and purpose of the manipulatives influence their teaching?

We might also look for evidence that has implications for what we are teaching teachers. We need far more data on how materials and activities work differently with students from different grade levels. We also need more information about which chunks of content and the manner in which they are taught are more appropriate for different groups of students. What really works?

We need classroom research on the teaching and learning of mathematics. Insights can be gleaned from studying activities of teacher trainees in a program which provides for classroom experiences with supervision and support from mathematics educators. The list of questions of interest is expandable but these examples highlight this need to learn more about the experiences of teachers as they attempt to implement the curriculum we advocate with live students in real schools.

Obviously not all of the answers to the questions of interest can be obtained by studying only trainees. We need to learn as much as possible about what occurs and how to influence it from as many sources as possible -- this experimental teacher training program being one. Experienced classroom teachers are another necessary source of study but there are others which also have potential such as mathematics educators doing some teaching of students in schools. Naturally there are limitations and problems associated with any single group which is why a coordinated effort is desirable.

Consideration should also be given to exploring the consequences of using portions of the limited time institutions allow for the training of teaching mathematics in field-based experiences. Does the time diverted from learning mathematics substantially decrease the confidence of the individuals and their ability to generate alternatives for planning instruction? Or does it work in the opposite direction with the relevant teaching experiences providing the incentive to learn more mathematics? Such questions suggest long range follow-up studies attempting to provide some answers.

In the continuum of teacher training -- assuming the process is never complete -- how do we maximize the benefits to teachers and ultimately their students? How do we decide what to do and where in the continuum it is going to provide the greatest payoff? Clearly some framework for making decisions about these training questions would be desirable, but to develop such a framework requires better understanding of the interface between the mathematics we suggest teachers use and the environment in which they must ultimately operate.

NEW MODELS FOR INSERVICE EDUCATION FOR TEACHERS:
A NEW APPROACH TO UNIVERSITY SERVICE TO SCHOOLS

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NEW MODELS FOR INSERVICE EDUCATION FOR TEACHERS: A NEW APPROACH TO UNIVERSITY SERVICE TO SCHOOLS

Dr. Richard J McLeod

According to Dr. John Porter, Superintendent of Michigan's Department of Education, "the retraining and upgrading of school staffs has become one of the most pressing issues in elementary and secondary education."[1] This concern is not unique to Dr. Porter, nor to Michigan. It is a national concern and is shared by nearly everyone involved in improving education in our schools.

Two interrelated factors contribute to this need: 1) the stabilizing population of teachers, and 2) the accompanying decline in teacher interest toward continual self improvement through traditional continuing education course work. There is an urgent need for new models of inservice that consider and account for these factors.

Stabilizing Teacher Population

Throughout the nation, the teaching profession is becoming increasingly stable. The situation in Michigan is not atypical. According to Michigan State Department of Education data gathered in the fall of 1976, fully 75% of all Michigan teachers now hold some form of permanent certification. This means that no further formal education is required to maintain their teaching certificate. Further, a very high percentage of our teachers are at, or very near, the top of their school's salary schedule. Thus, the incentive for taking additional university course work is low. The long term commitment to attend regular classes, study, pass tests, write papers, etc., is an unattractive alternative to "not knowing." The number of teachers in this situation will continue to increase. Declining school enrollments are resulting in a rapid decline in the employment of beginning teachers. A recent document from the State Department of Education summarizes the situation succinctly:

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[1] Michigan State Department of Education. (Professional Development for School Staffs, The Michigan Approach). 1977. Foreword.

> "With declining student enrollments and provisions in most master contracts for lay-offs to be made on a seniority basis, it is predicted that the professional work force will tend to include more persons: 1) with extended experience; 2) at the maximum salary level; and 3) with higher levels of college or university preparation than ever before. Since preparation tends to be completed within the first six years of employment, this same trend will produce a work force whose most recent higher education experience will become more distant with each passing year."[2]

One might argue that the increasing antiquity of a teacher's last experience in higher education is of little consequence in light of other experiences that are supposedly received. However, Oberlin and Sanders,[3] in their research on the subject matter knowledge of teachers, found that 10% of the 6th grade students were already more knowledgeable in science than were 47% of beginning teachers. Further there is little reason to expect this understanding to increase as the teacher becomes more experienced unless explicit attempts to do so are made. Thus, we have an obligation to develop appropriate materials and delivery models that can, in fact, increase teachers' understanding of science and mathematics and their consequent ability to help students understand these subjects. Further, the delivery models must be capable of reaching the already large and increasing number of teachers who are relatively unreachable through present channels.

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[2] Ibid., p. 4.

[3] Oberlin, Lynn and Lowell B. Sanders, "A Comparison of the Science Content Knowledge of Graduates from Florida's New Elementary Program and Graduates who had Their Science Education in a Traditional Course." Science Education, 57 (3):331-334. (1973

Rogers and Svenning[4] cite our failure as educators to meet this challenge of influencing passive or slightly resistant practitioners. They point to the need, even the responsibility, to communicate, persuade, and actually promote change and growth in education.

Any mechanism designed to promote change and growth in education must take into account the stabilizing teacher population and its associated constraints. As the teaching population stabilizes, traditional continuing education courses attract fewer numbers of teachers from any one school system. Yet, our experience clearly indicates the need for some critical mass of informed and interested teachers within a system if planned change is, indeed, to take place. The older mechanisms, such as free tuition, are insufficient to attract large numbers of teachers who are already at the top of the salary schedule.

However, our past experience with schools, coupled with consultation with large numbers of teachers and administrators, the Michigan Education Association, the Michigan Department of Education, and numbers of our colleagues at this and other universities suggest the directions for a new model of inservice. There is general agreement that even though a majority of teachers are no longer interested in regular university course work, they still desire new knowledge input provided that it:

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[4] Rogers, Everett M. and Lynne Svenning. Managing Change. Report to the San Mateo County Board of Education, 1969. p. 58.

a. is of short duration and specific in topic,

b. occurs on school time or has some other incentive, and

c. has immediate application to the classroom or satisfies a self perceived "need to know."

Any new model for inservice must meet these constraints.

Directions Suggested by the Cooperative Extension Service in Agriculture

The problem that agriculture faced in the 20's (introducing modern farming practices to passive or resistant farmers) is not unlike our present problem in science education. There is considerable similarity in the passivity and resistance to new knowledge and innovative practices of the farmer of a half century ago and that of science and mathematics teachers of the present. Farmers can be considered somewhat autonomous individuals within an implicit organization within a community Teachers likewise have a high degree of autonomy within the classroom, although the organization (school) is explicit. However, in terms of communication with other members of the organization, teachers tend to be much more isolated and their practices less visible to other members of the organization than are farmers.

Not only is the entry of outside information made difficult by this isolation, but there is a paucity of exchange of relevant information among teachers within a building. Whereas many of the farmer's practices were clearly visible to other interested farmers, most teachers' practices are private.

According to Miles (1969)[5], communication among teachers about their own teaching practices is relatively small. There are many negative forces acting to suppress communications, e.g., fear of ridicule, authority, parents, etc. This norm tends to limit seeking new information from all sources. Miles also points out, however, that the research clearly indicates that if real "gut level" communication took place among teachers . . . "about their own teaching inventions, we might expect a general rise in innovativeness." This view is also supported by Havelock[6] in his citation of the importance of user openness.

The need, then, is to actively change the teacher norm from one of not seeking information to one of seeking both information and assistance in improving instruction in individual classrooms. This requires both readily available resources and a mechanism for promoting and facilitating their use. It is here that the model suggests a linking agent analogous to agriculture's county agent.

Rogers and Svenning[7], referring to the situation in agriculture, point to the paucity of communication between researcher and practitioner when the printed word was the primary vehicle of communication. When the interpersonal channels of extension specialists and county agents were interposed between researcher and practitioner, the rate of adoption of innovations increased significantly. They state that there is a great deal of similarity between the situation in education today and that of agriculture before the county agent. Havelock, in fact, calls for an ". . . educational extension service which includes well defined linking roles at various levels."[8]

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[5] Miles, Matthew B. The Development of Innovative Climates in Educational Organizations. Research Note EPRC-6747-10. 1969. p. 13-14.

[6] Havelock, Ronald G., et al., Planning for Innovation Through Dissemination and Utilizations of Knowledge (Ann Arbor, Michigan, Center for Research on Utilization of Scientific Knowledge, Institute for Social Research, The University of Michigan, 1971) pp. 6:7-10.

[7] Op.Cit., P. 58

The "well defined linking roles" cited by Havelock are also an important attribute of the Cooperative Extension Service in Agriculture. First, the Agent becomes a single access point for information. No comparable single access point exists in science and mathematics education. If a mathematics teacher needs information on the role of the hand held calculator in 9th grade mathematics, he probably doesn't know where to obtain information. Should he go to the mathematics department or to the College of Education? Whom should he ask within the department or college? If a university is not close by, from whom should he seek information. In an analogous situation, a farmer would go to the County Agent, who, in turn, would identify the appropriate resource and link the user and resource. Thus, the resource people, agents, and users have well defined linking roles.

Finally, an effective linking agent must be trusted by the users as a credible source and one who understands their problems.

Rogers and Svenning state,

> "A change (linking) agent is most helpful when he is an integral part of the system in which he is attempting to promote change. He tends to be more successful in his role if he understands the system and the specific needs of its members, if he can work with his clients to define their 'felt needs', and if he is perceived by his clients as a credible source and if he provides advice and support for his clients during their experimentation with innovation."[9]

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[8] Op. Cit., pp. 7-38.

[9] Op. Cit., p. 58.

Thus a linking agent in education might well be a trusted teacher from within the school system.

In light of the works of Havelock, Rogers, and others, it seems apparent that an essential component of an effective educational in-service system is an agent who can actively work with teachers to explicate their needs, both perceived and unperceived, and bring to bear appropriate resources.

The agricultural model also suggests the value of the printed word to augment oral communication.

Rogers and Svenning[10] hav[illegible]ted the ineffectual communication when the printed word was the primary vehicle of communication. However, the extension bulletin as an adjunct to face to face communication has demonstrated success. The bulletin as a follow-up, an advanced organizer, or as a supplement remains an effective tool of the Cooperative Extension Service. It seems reasonable that short, topic specific bulletins on relevant content and methods in science and mathematics would also be effective adjuncts in improving education.

In summary, then, there is an urgent need to provide for the continuing staff development of the population of science and mathematics teachers who are becoming increasingly apathetic to traditional mechanisms for new knowledge input. The model t[illegible]e described recognizes and accounts for the constraints imposed by teachers and proposes to test the viability of utilizing an active trained linking agent, a large variety of resource specialists, and extension bulletins as contributing elements to producing knowledge entry, exchange, and utilization.

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[10] Ibid., p. 58.

Assumptions

In describing the model, we make the following assumptions:

1. There are a limited number of areas of need that represent large overlap for many teachers. This is particularly true within buildings and systems due to common curricula, similar social forces, etc. Further, while the first priority of each will not likely be the same, it is reasonable to assume that the first ten priorities will have a high degree of commonality among teachers within any particular system. Thus, it is a reasonable expectation to be able to produce a finite set of inservice packages that will have high impact on the needs of a broad spectrum of teachers.
2. Teachers do not perceive themselves to be a completely science naive audience. Virtually, all of them have been required to take some science. For many, particularly elementary teachers, this only resulted in confirming the conviction that no further science should be taken. Nevertheless, they are adults, college graduates, and have some background or exposure to science. In many cases, this background is represented by some rather significant gaps in conceptual and content knowledge, and fears associated with pursuing additional science. Thus, we assume that a first approach must be aimed at filling gaps in a way that does not require high commitment from the teacher for extended periods of time, does not present a high level of threat to the teacher, and yet, produces significant gain in knowledge in selected areas.

We further assume that the satisfaction obtained in producing these knowledge gains will result in a teacher being less reluctant, perhaps even eager, to take further science.

3. The mini-courses, for many teachers, are not an end in themselves, but will provide the stimulation for more indepth study of science through regular university courses, self study, more active participation in professional societies, etc. We assume that, generally, these back up resources are available through the more traditional channels of continuing education.
4. That an internal change-agent can effectively stimulate the faculty to seek appropriate input on how to improve their teaching of science and mathematics.
5. That some increase in the teacher's knowledge base is better than none at all. The present situation demands that we consider new alternative delivery systems for providing relevant knowledge input or teachers are unlikely to obtain it. If we remember that 75% of our teachers no longer need to take further course work to retain their certificates or to receive increases in the salary schedule, then we must engage in efforts that hold some promise for meeting the need of continual maintenance and upgrading of teachers' subject matter background and teaching skills. That an internal change-agent can effectively stimulate the faculty to seek appropriate input on how to improve their teaching of science and mathematics.

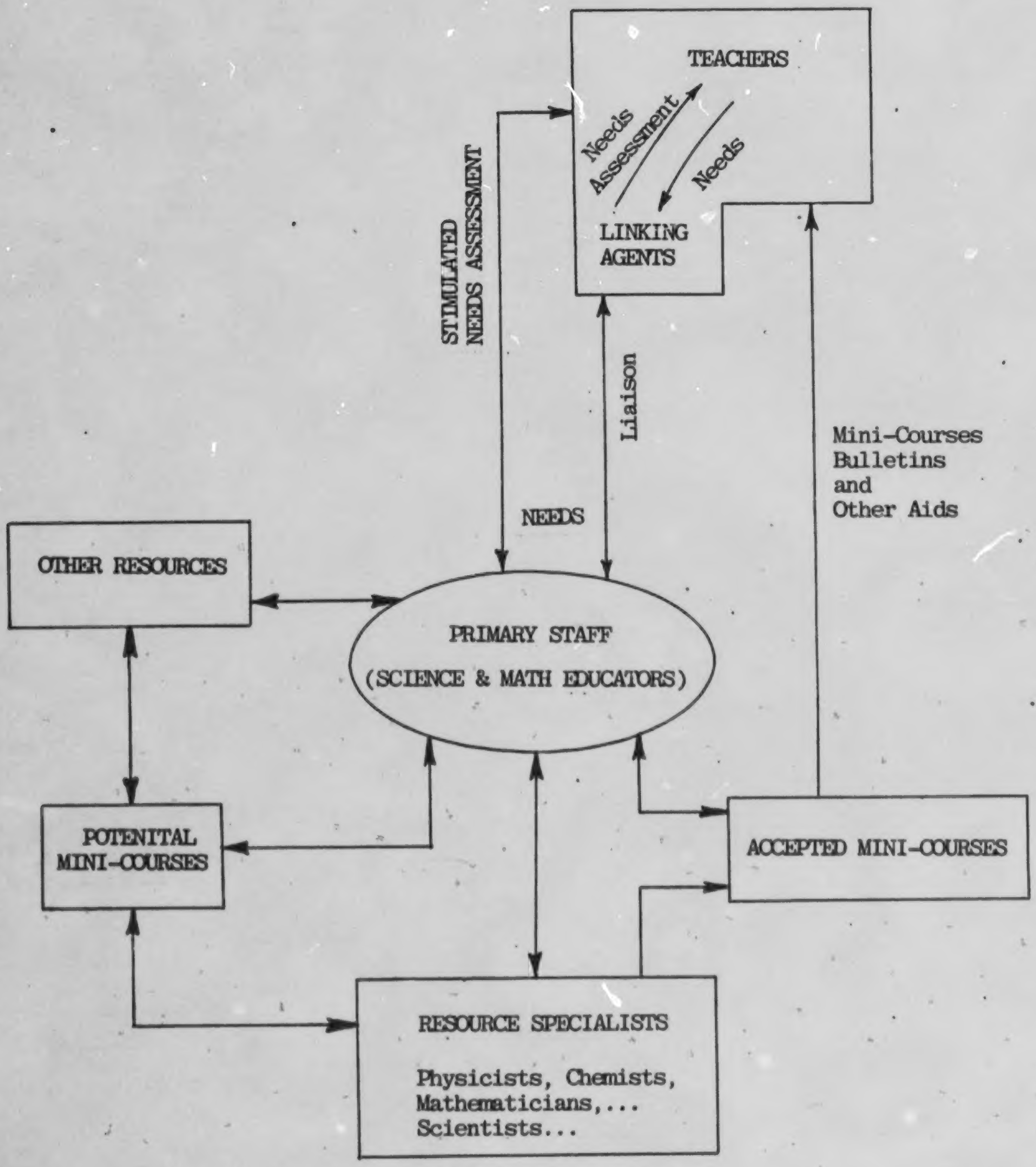
General Strategy of the Model

The general strategy of this model provides for the upgrading of the background knowledge and teaching skills of science and mathematics teachers during the school's regularly scheduled inservice days. The primary vehicle of instruction will be mini-courses and associated bulletins delivered by resource specialists. Trained linking agents will conduct stimulated needs assessment to determine teacher needs and help plan effective inservice days to meet these needs (See. Fig. 1).

Inservice Day

This project proposes to use the inservice day as an entry into schools for three reasons: First, this makes inservice instruction compatible with teachers' stated desires. It is of short duration (one day at a time) and it occurs on "company" time. Second, it is a way of reaching all teachers within a given district. Even though 75% of the teachers may have no external incentive to take additional course work, they must participate in the contractual inservice days which are a part of the regular school year. Third, neither the administration nor the teachers have been particularly successful at planning effective programs for inservice days. This is an opportunity for schools to receive assistance in planning and implementing quality inservice programs.

Once a school system decides to participate, the first step will be to identify a staff development committee within the school system that will help to assess needs and plan the inservice days. In some schools, this type of committee is already functional. If not, we will work with any appropriate existing committees, the local education association, and the administration to form a staff development committee that can cooperate with


TEACHERS
Needs Assessment
Needs
LINKING AGENTS
STIMULATED NEEDS ASSESSMENT
Liaison
Mini-Courses
Bulletins
and
Other Aids
NEEDS
OTHER RESOURCES
PRIMARY STAFF
(SCIENCE & MATH EDUCATORS)
POTENITAL MINI-COURSES
ACCEPTED MINI-COURSES
RESOURCE SPECIALISTS
Physicists, Chemists,
Mathematicians,...
Scientists...

university staff to assess needs and plan effective inservice days. Once the committee is established, our university staff will work with the committee to identify initial needs. To facilitate this effort, we will use a list of potential mini-course topics generated as a result of previous experiences and surveys of teachers' needs. It is expected that this list will be sufficiently comprehensive to provide guidance and stimulation to the teachers. They will be free, however, to identify potential topics from the list as well as to request topics not listed. At this time, the total inservice program for the first year will be designed. It is anticipated, however, that some changes in that design will be necessary as a result of the first inservice day. For example, we hope that the mini-courses will be sufficiently stimulating that many teachers will request additional work on the same topic or be stimulated to request topics not previously identified. Thus, the plan for subsequent inservice days may require modification to accommodate this interest.

The Mini-Course and Bulletin

Using the inservice day produces time constraints on the knowledge input. Whatever is offered must fit the constraints of that day. Further, many schools have a combination of full and half inservice days. Our greatest chance of success rests upon our ability to provide meaningful, high impact content within a three hour limitation such that we could accommodate either the half or the full inservice day. Thus, with the equivalent of two full inservice days within the school year, any one teacher would be able to attend four different mini-courses.

Still another rationale for the mini-course concept rests on teachers' unwillingness to commit themselves to extended periods of instruction. Most teachers are willing to attend one or two mini-courses in a particular topic with the freedom to make different choices at subsequent inservice days. However, the real impact of this effort will derive from the long term joint school and university commitment. Thus, the university can continue to develop mini-courses of greater depth for those schools that have been in the program for a longer period of time. In time, it is quite conceivable that a teacher would obtain considerable depth of knowledge in a wide range of topics through this vehicle. Further, we anticipate that this vehicle will stimulate teachers to request long term commitments in the form of more extended contact, regular university courses, or consulting arrangements.

We propose to develop an array of mini-courses that address the improvement of instruction through three major areas:

1. Science and mathematics content
    a. basic content in the recognized disciplines primarily aimed at the teacher who is outdated, teaching out of his major, or teaching science and mathematics for the first time due to staffing reductions.
    b. interdisciplinary content such as energy education, environmental education, career education, etc.
    c. enrichment content.
2. Pedagogical content
    a. the teacher as a clinician--the teacher-learning process.
    b. modern instructional programs--inservice and awareness.
    c. methods and techniques--evaluation, laboratory management, maintenance of living organisms, the hand held calculator, etc.

3. Research

   a. results of appropriate teacher-learning research and their applications to the classroom practice.

   b. encouragement to become part of research models in order to broaden teacher understanding of the data base.

   c. encouragement to bring teaching problems to the university for further research.

These courses would be limited to three hours and a single topic. The topics would derive from teacher input as well as the college educator. Thus, many of the topics would be designed to stimulate teachers to expand their perception of needs and others would require college faculty to become more responsive to the educational community they serve.

Bulletins will also be produced to complement each mini-course topic. In addition to their intrinsic value to the teacher, they have the added value of imposing structure on the delivery system. Havelock[11] points to the need for this consistency in terms of structure. He cites the need for structure at all levels, but structure of the message and the medium are of particular concern to this project. First, Havelock repeatedly cites the need for human contact, as does Rogers and Svenning. In all cases, the primary medium of delivery will be live presentations using methodology consistent with modern curriculum programs in the disciplines. However, in order to further impose a structure, we propose a bulletin for each mini-course delivered, similar in form to those produced by the Cooperative Extension Services in Agriculture. The bulletin and the live delivery will have a consistent format in that each will carefully identify the topic to be addressed, the task to be accomplished, and the strategy formed the basis for much of the recent research at the Science and Mathematics Teaching Center and, we believe, offers considerable promise in improving the efficiency and effectivensss of the mini-course instruction, as well as possibly producing carry-over to the teachers' classroom practices. In addition to providing a needed structure for the delivery system of each mini-course, it is consistent with Havelock's concept of message linkage as it relates to other messages that have been directed to the user.[12]

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[11] Op. Cit., pp. 6-14.

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The identification of appropriate staff, development of mini-courses, and the preparation of bulletins are key elements in this model.

We must utilize a variety of resource specialists, scientists, mathematicians, and science and mathematics educators in order to successfully respond to the needs of teachers. In so far as is possible, our primary staff will identify faculty within their areas of expertise who are known to work well with teachers. However, the number and variety of resource specialists needed will necessitate the inclusion of faculty who are not accustomed to working with teachers nor are aware of their needs. A major element, then, of the model would be a primary staff, knowledgeable in the needs of teachers, who will assist the resource specialists in the development of mini-courses and bulletins that are appropriate for teachers.

The mini-courses will be such that, generally, a meaningful approach to the topic can be accomplished in three hours, although it is recognized that it is difficult to treat some areas, particularly basic science, in but a superficial way in this period of time. But many teachers who are permanently certified have no intention of taking a full course in, for example, physics, even though they have no physics in their background and may be now called upon to teach some physics within a general science course.

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[12] *Ibid*., pp. 11-21.

However, particular topics, such as lens optics, waves, or simple electric circuits, might conveniently be taught in one or two such mini-courses. Further, if teachers found these courses to be intellectually stimulating and helpful, they might be prompted to take additional mini-courses or even regular university courses. The key is to provide the teacher with information on a "need to know" basis (with appropriate stimulation to enhance that need) and in packages that are not formidable.

The primary responsibility of developing such mini-courses will be that of the faculty member (resource specialists) who will deliver them. However, the primary staff, each of whom have extensive experience with teachers and school instructional materials in their field, will carefully select and then work on an individual basis with each resource specialist to provide input on the level, the approach, the kinds of materials that are being used in the schools in that discipline, and particular teacher concerns. After the specialists have developed one or two mini-courses, we have every hope that their enthusiasm for working with schools will increase and we will develop a positive and continuing communication link between the schools and large numbers of university faculty.

The Linking Agent

The research cited, together with our experiences during the last decade of Resource Personnel Development suggests strongly the superiority of an internal (vs. external) agent, particularly in a collaborative role with university faculty. For these reasons, we propose to identify potential linking agents from within the school structure. These people would receive special training and then work with our staff in a collaborative mode to affect change within the system.

The selection of potential linking agents is to be a key factor in their ultimate effectiveness. It appears that the best chances for the linking agents' success rest upon our ability to identify the opinion leaders within a school system and provide them with appropriate training necessary to enable them to accommodate the role of a linking agent. To do this, a questionnaire will be produced and distributed to all teachers within the participating systems. The results will be used to identify those teachers in the school who other teachers look to for sanction or advice. At the same time, we will seek information that will tend to indicate potential innovators and defenders. The latter information will be used during the training program for the linking agents. Once we have some indication of the identity of the opinion leaders at each school, we would then work with the administration and the local teachers' association to identify the most likely candidates for linking agents. Once the potential linking agents have been agreed upon, each candidate would be interviewed to further assess their interest in, and attitude toward, functioning in the role of a linking agent.

The final selection would probably include three or more linking agents per school system in order to adequately address the needs of elementary through high school teachers. The actual number would vary depending upon the size of the school system and its social structure. There should also be some incentive for the linking agent, possibly in the form of released time or extra compensation.

The training program for the linking agents would consist of approximately three weeks of concentrated effort in the areas of change agent and interpersonal skills, teacher-learner diagnostic skills, and knowledge of the available resources. Thus, the agent would have some knowledge of helping teachers diagnose their teaching-learning problems, knowledge of available resources that might address these needs, and the skills necessary to help facilitate entry of and utilization of these resources.

Each selected school system would be represented at the three week training program by all selected linking agents and one full time administrator. Although the linking agent will have the major responsibility for stimulating teacher perception of needs, his ability to function can be facilitated or impaired by administrative action. Our experience suggests that once we can produce a nucleus of concerned individuals (consisting of teachers and administrators) within the school, we can then work effectively toward helping them in decision making processes. Havelock[13] points out that traditionally, we have been concerned with a "downward" flow of information from administrators to workers. Partially, this is the kind of information flow stimulated by administrator workshops. However, he points to the need for horizontal (teacher-teacher and administrator-administrator) information flow and "upward" (teacher-administrator) flow. Thus, we propose to establish teams consisting of teachers and administrators. During the workshop itself, there will be sustained effort to build this team into an effective working and communicating unit. This will subsequently enhance the upward and downward flow of information within the school system as well as the horizontal flow. It will also provide our staff with easy entry into all levels of the system. There is, yet, another reason for inviting teams of school personnel from each system rather than individuals. Our research, as well as that of others involving

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[13] Ibid., pp. 6-14.

Resource Personnel Development, indicates that the supportive function of teams of individuals greatly enhances their ability to function in their home environment, provided there is a pre-established common bond. We believe this criterion is satisfied more than adequately by their involvement in this three week training program.

In summary, we believe that the proposed model holds promise for providing for the maintained and upgrading of teaching knowledge and skills on a continuing long term basis. Further, it will impact entire systems and, hopefully, promote a mode of information seeking and sharing as new needs are perceived and resources identified. Both the Michigan State Department of Education and the Michigan Education Association have endorsed this model as having potential for meeting the needs of inservice education in Michigan.

NEW MODELS FOR INSERVICE EDUCATION FOR TEACHERS: A NEW APPROACH TO UNIVERSITY SERVICE TO SCHOOLS

Presented by Dr. Richard McLeod

Rapporteur's Report

by Dr. David Schulert

Participants agreed with Dr. McLeod concerning the rational and need for a new approach to inservice education:

1) We must depend on the teachers we have because we no longer have the influx of new teachers to update our programs.

2) The classroom is a private domain, with a minimum of communication from classroom to classroom.

3) Teachers want to improve their performance, but only on their own terms.

There were mixed feelings about the effectiveness of the inservice days:

1) Is required participation a plus or a minus?

2) Are there enough teachers in a small school that have the same needs and desires to make this approach practical?

3) Are inservice days being pre-empted by other activities so the people who need the training are not available?

Consideration should be given to released time for an individual teacher or group of teachers to participate in an inservice activity requested by them without the necessity of dismissing the whole school.

Dr. McLeod's concept of a 'linking agent' received much favorable comment, however, we did not get to the subject of who this person would be and how he would be trained. We agreed that it must be someone with credibility with teachers.

General Comments:

Districts might tie reading together with science and/or math by working on reading in the content areas. This is appropriate for early elementary through twelfth grade.

Information kinds of inservice could be furnished by short bulletins or cassette tapes on specific topics. An effective inservice technique is to find someone who is willing to try or is already doing, and let others observe.

TOWARD MORE MEANINGFUL LEARNING
IN SCIENCE AND MATHEMATICS

Carl J. Naegele
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TOWARD MORE MEANINGFUL LEARNING IN SCIENCE AND MATHEMATICS

Dr. Carl J. Naegele

I. Introduction

The aim of this paper is to suggest a few sample and straight forward teaching strategies which have emerged from recent educational research and have proven to be useful in a variety of contexts. These strategies should be of value to teachers, designers of instructional materials, and others involved in education. An attempt is made to show a particular view (theory) of how intellectual growth proceeds from birth through adulthood and how a knowledge of this process might suggest to educators in science and mathematics (and perhaps other areas) ways in which to improve, through their teaching, the intellectual development of their students.

This view of intellectual growth includes a consideration of how information is organized in the minds of learners, how forgetting occurs, and in general how human beings are able to assimilate vast quantities of information and organize it into mental structures that maximize its utility in both problem solving and in facilitating the learning of future related information.

The theory argues for a general-to-specific view of cognitive development which considers concept development to begin with rather vague general perceptions which are largely intuitive, descriptive, and qualitative. As learning proceeds, these general concepts are seen to have components which are of a less inclusive or more specific nature.

The organizational structure of concepts is thus seen to be hierarchical in nature, where the more general and inclusive concepts are found at the apex. A progression from general to specific (or whole to part) is shown to be natural to both human development and human thought, and several parallels from biology, Gestalt psychology, the scientific enterprise itself, and other areas are discussed.

The basic idea of general-to-specific concept development is then articulated more thoroughly in a basically simple yet comprehensive learning theory put forth by David P. Ausubel.

Finally, an attempt is made to show how a few simple principles of this theory can be put to use in a great variety of situations to improve classroom teaching.

It might be of interest to the reader that the organization of this paper is structured on a general-to-specific paradigm.

II. General-to-Specific Paradigms

General-to-specific patterns seem to be a natural and fundamental characteristic of the development of both physiological and cognitive processes in human beings. We find this phenomenon reflected in biology, Gestalt psychology, in the scientific enterprise with its emphasis on the elaboration and refinement of global theories, in philosophy, etc. The following is a brief discussion of some of these areas.

A. Cell Differentiation

All living organisms begin as a single undifferentiated cell. This single cell divides into two, which in turn divide to form four, which in turn divide to form eight, etc. as growth and development progress, subsequent cells begin to take on specialized characteristics. In man, some begin to specialize in building up bone tissue, others in forming the heart, etc. until at birth we have an organism with all of the essential parts necessary for survival.

It is interesting to note that, with rare exception, cells become specialized only to the extent that they contribute to the functioning of the organism as a whole. For example, leg cells continue to divide until the entire leg with its many specialized parts is complete. Each part contributes to the functioning of the leg and the leg itself contributes to the functioning of the individual.

Later we will show how a similar process can be used to explain cognitive development.

B. Early Perceptions

Consider the development of our ability to process and attach meaning to visual stimuli. During our first encounters with our environment the objects which we see appear as fuzzy images, some big, some small, some bright, some dim. This is our earliest "concept" of objects. As time passes, we develop the ability to distinguish between different kinds of shapes, we are able to distinguish our parents from other adults, etc. In other words, our concept of an object becomes progressively more differentiated. As we encounter new objects, we relate their characteristics to our general concept of an object and establish similarities and differences between other objects and classes of objects. The degree to which we carry out this discriminatory process depends largely on the characteristics which we think are important. When we meet another person for the first time, our first impression is that we are in fact encountering another human being. We then proceed to distinguish other characteristics: height, weight, hair color, speech patterns, facial characteristics, etc.

In later years we encounter more complex conceptual networks, but if the attempt is made, we can usually relate new concepts to the "fuzzier" intuitive notions we learned in the past. In this way, the new knowledge broadens these ill-defined general notions or concepts and allows us to make finer distinctions.

Since the development of concepts in individuals seems to progress naturally from very general intuitive perceptions to more specific and complex distinctions between members of the same class, a model reflecting a hierarchical arrangement of cognitive structure with respect to generality and inclusiveness would seem logical.

C. Gestalt Psychology

This fundamental principle views psychological development as starting with the complex, in which broad general concepts are first to form and in which the parts have little or no meaning except with respect to the whole.

The word "Gestalt" is translated to mean "form" or "configuration." When we teach in a general-to-specific progression, the learner sees more clearly the "form" or structure of the disciplines and is thereby able to more easily relate new information and experience to it.

The importance of teaching the structure or "form" of a discipline is important if we expect learners to develop both an understanding of the knowledge and an appreciation for it. Its intellectual and aesthetic qualities are thus merged into one. Pirsig (1974) gives an excellent treatise on the practical utility and aesthetic merits of hierarchical knowledge structures.

D. The Scientific Enterprise

An interesting parallel is seen between the development and differentiation of concepts by individuals and the development and articulation of paradigms by the scientific community at large. Both require a substrate of knowledge, whether it be general concepts held by individuals or principles and theories held by the scientific community, to allow for the meaningful incorporation of new information into the existing structures (Bowen, 1974). The periods of most rapid growth in science have closely followed the development of new models which served to organize a morass of seemingly unrelated phenomena. Intellectual growth in individuals is facilitated when organizing patterns are used to provide a unifying theme to seemingly independent facts and concepts.

E. Popularity with Students

General-to-specific presentations of subject matter and also questioning strategies appeal to the natural curiosity of students. In a unit on the solar system, we would probably begin with questions such as "What is the solar system like?" We would discuss the general configuration of the planets and sun first, then explore its components in progressively more detail: "What are the planets like?," "What is it like on one of Jupiter's moons?" etc.

The best-selling college physics text for non-majors (Hewitt, 1977) is based on a conceptual development of ideas that largely follows the general-to-specific progression.

Through questionnaires given to students enrolled in physics courses at different levels and at different universities we have learned that these students prefer, by a margin of greater than 70 percent, a general-to-specific (deductive) ordering of instruction as opposed to a specific-to-general (inductive) approach (Naegele, 1976).

F. Elaboration Theory

According to Merrill (1976), the most efficient method for teaching mathematics concepts and problem solving is to begin with a general rule, give several examples, then practice on specific problems related to the general rule. Initially the learner perceives the general rule essentially as an abstraction which is later given meaning through more specific examples and problems.

G. Hierarchical Structure of Concepts in the History of Western Knowledge

Since ancient times, man has had a natural tendency to organize his civilization on hierarchies. Kingdoms, churches, governments, armies, modern business and industry, universities, tables of contents of reference materials, science, mathematics, technology, etc. have all been structured on hierarchies.

H. Logical Versus Psychological Organization

Often these hierarchical structures which we have been discussing are developed collectively by large numbers of people, sometimes spanning many centuries. The result is what might be called the logical organization of the knowledge. An individual learner may very well require a greatly modified version of the hierarchy to assimilate it into his own cognitive makeup. In this sense it might be termed a psychological organization.

III. Ausubelian Learning Theory

Thus far we have attempted to show how hierarchical structures cut across many aspects of human knowledge and thought. Since this tendency seems to be natural to cognitive functioning, it seems reasonable that teaching strategies could be vastly improved by taking this into account.

Until recently, teachers have had little more than a list of unconnected research results, do's and don'ts for classroom teaching, "laws of learning" (e.g., Thorndike's), implications for teaching from Piaget's studies in developmental psychology, and the like. Each of these have provided helpful hints for improving particular aspects of teaching but none has provided a comprehensive model for explaining the processes by which human beings assimilate vast quantities of information and retain it in such a way that it facilitates future learning.

We are fortunate that such a model is now available to us in the learning theory put forth by David P. Ausubel (1968). Attributes which make this theory attractive are 1) its basic simplicity,

2) its basic focus on a general-to-specific learning paradigm, 3) its ability to provide guidance in developing effective teaching strategies for students of varying interests, aptitudes, backgrounds, learning styles, and the like, and 4) the parsimonious manner in which it is able to explain the vast majority of research findings related to the teaching/learning process.

A. Fundamental Principle

The fundamental principle on which this theory is built is that learning is influenced more by what the learner already knows than by any other single factor. This implies that effective teaching must begin with a consideration of the prior experiences and existing general knowledge structures possessed by our students. Once we have done this, we can then proceed to develop instructional strategies which result in what Ausubel calls meaningful learning.

B. Meaningful Learning

Meaningful learning occurs when new knowledge is associated with existing general concepts in a nonarbitrary and substantive (nonverbatim) manner that allows for adequate internalization of the new information. This often requires that the information be reorganized or restructured idiosyncratically by the learner. In the process, existing general concepts are broadened and enlarged while the new specific information is given meaning and anchorage by virtue of these associations.

In contrast to meaningful learning, is rote learning. In rote learning, these associations are not made. Existing concepts remain unchanged and new information is generally forgotten rapidly. One practice to which we all adhere to some extent is to mimic the same kinds of teaching that we experienced as students. Unfortunately many of our well-meaning teachers operated in a manner which encouraged and rewarded rote memorization rather than meaningful assimilation. Remember how you would steam after receiving no credit for a perfectly acceptable synonym on a fill-in question for which the teacher wanted a particular word. Students quickly adopt a rote learning strategy when logical approaches result in "failure."

New knowledge, whether it be facts, concepts, propositions, processes, etc., can result in intellectual growth only if learned meaningfully. Meaningful learning can occur both in discovery learning and in reception or expository learning. The key considerations are whether the information is potentially meaningful (has some internal consistency), the learner's availability of existing concepts that can be related to the new information, and the learner's disposition to learn meaningfully. A deficiency of any of these components invariably leads to rote memorization if not corrected.

A mistake teachers frequently make is to teach on an inappropriate level for the average student. Students new to a particular area of knowledge who are thrust into abstract and analytical concepts, quickly find defeat and frustration, with resulting lack of interest and motivation. All students at some point must be exposed to the concrete, directly observable elements in a conceptual area before the more abstract ideas to which they relate can be meaningfully learned.

C. Subsumption

This aspect of the theory is concerned with the hierarchical arrangements of concepts in the cognitive structures of individuals. The general-to-specific nature of this hierarchical arrangement is reflected in the process called subsumption. As new information is received by the learner, it is viewed to play a subordinate role to existing general concepts to which it is related. The new information is subsumed under a more general concept (subsumer) possessed by the learner. In this way new facts are organized around a general theme, which results in the formation of meaningful associations both among the new knowledge elements as well as between the new knowledge elements and existing knowledge.

Another characteristic of subsumption learning is that it tends to facilitate future related learning. Even though the new knowledge may be "forgotten" to varying degrees in the future (obliterative subsumption), the existing concepts, having been broadened and strengthened by the new knowledge, are then able to facilitate more effectively the learning of future related information.

In rote learning, not only is the new knowledge more quickly forgotten, but more importantly, having failed to broaden existing concepts, the new information is ineffective in contributing to the intellectual growth of the learner.

D. Progressive Cognitive Differentiation

This principle is similar to subsumption learning but considers the learning process over a longer period of time where many concepts might be involved. As we develop over the years, vague and ill-defined notions become subdivided into a hierarchical structure which is progressively differentiated to varying levels of detail, depending on the interests and abilities of the learner and other factors such as external motivational stimuli. As the learner progresses in the understanding of concepts in a particular area, existing concepts take on a less amorphous character.

E. Integrative Reconciliation

To maximize the impact that new knowledge has on existing cognitive structure, it is necessary to cross-reference related ideas to other areas or disciplines. The value of any particular knowledge element is directly related to the degree to which it cuts across different concept areas. This integrative process results in a higher degree of discriminability between similar ideas, serves to clarify meanings, and provides increased anchorage through additional associations.

Each major aspect of this theory was developed from a broad base of research findings reported over many years. Since the time when this theory was first published a number of studies have been done to test various aspects of it. With the exception of a few isolated studies, the theory has been convincingly supported by empirical research and in finding application in an increasing variety of contexts. It is not within the scope of this paper to enumerate these studies.

IV. Examples Applying Ausubelian Learning Theory

In this section several examples from science and mathematics are given to show how a consideration of the cognitive development of our students, coupled with the application of a few simple principles of

Ausubelian learning theory can provide valuable guidance in developing classroom teaching strategies. Our central goal is to develop strategies which will promote intellectual growth in our students. It is argued that optimal learning will occur when deliberate attempts are made to order instruction in such a way as to progressively differentiate relevant concept structures.

The basic procedure is to order the conceptual development in a given unit of instruction from general-to-specific. This suggests that we should begin by introducing first those ideas or concepts which are at the highest level of generality and inclusiveness and have students subsume new related information under these concepts as we progress.

Of the following four examples, two are taken from mathematics (percentage and measurement) and two from science (resonance and energy).

A. An Example from Mathematics (Percentage)

Consider the difference between teaching students the concept of percentage in mathematics by beginning with the arithmetic manipulations used to compute decimal percentages, versus an approach where one proceeds by first discussing with students on a qualitative level some of their intuitive notions about percentages gained from past experiences (e.g., discussing the relative sizes of physical objects in terms of twice as large, half as large, one quarter as large, etc.) and then associating these with the concept of percentage and decimal numbers. In the first case (rote learning) the students are likely to perceive the notion of percentage as a pure mathematical abstraction with little relevance to existing concepts of relative size, or number, or to concepts of fractions, etc..

In the second case (meaningful learning) the process of determining percentages through decimal multiplication is related to existing cognitive structures in such a way that the students' general concept of percentage is enlarged and can now be applied to a wider variety of situations, problems, etc.. Furthermore, when new related ideas are encountered in the future (percentage population increase, income tax, minimum daily requirements of vitamins, etc.) they will be learned more rapidly and more meaningfully by virtue of the existence of a more complete and more powerful conceptual base to which associations can be made.

B. An Example from Mathematics (Measurement)

Most mathematics teachers are probably familiar with the suggestions for teaching measurement put forth by the National Council of Teachers of Mathematics (1974). An elementary school curriculum for teaching measurement is recommended which begins in the lower grades with perceptual observations (comparing relative sizes of objects), then progresses to numerical measurement with unit objects (determining the number of paper clips it requires to represent the length of an object), and concludes with measurement using calibrated instruments (determining the length of a pencil in centimeter units to the closest tenth). The attempt here is to avoid teaching measurement as a number of rotely learned skills, but rather to develop the concept of relative size which can be differentiated to varying units and to varying degrees of accuracy depending on the individual learner.

C. An Example from Science (Resonance)

Suppose in a unit on sound we are attempting to teach the concept that sounds coming from wind instruments are produced by resonating air columns. To many students, the above statement is pure abstraction and little meaning is associated with the concept. On the other hand, we could precede the above statement with a consideration of the kinds of experiences relative to resonance that we can assume our students have had and use these to develop and differentiate the concepts of resonance, to include a meaningful understanding of resonating air columns. Certainly most of them would have had experiences with swings as children (a system with a natural vibrational frequency). This is a concrete example which is directly observable and serves as a good starting point. They could easily understand that increasing the amplitude of the swing is a result of applying a force at just the right intervals. Namely, that the oscillation will increase in amplitude if the input frequency is just equal to the natural vibrational frequency. We might even demonstrate this effect or arrange it as an activity so that it can be adequately internalized. We can then proceed to other familiar examples such as the resonant vibration of an automobile undercarriage at particular speeds when wheels are out of balance. When a sufficient number of directly observable or otherwise easily understood examples of resonating systems are considered, the student then begins to develop a firm grasp of the concept of resonance and the requirements for a system to be set into resonance. These ideas then become useful analogues when the student encounters the more obtuse and not directly observable resonance phenomena such as resonating air columns, molecular resonance, electrical resonance, etc.. Without a well differentiated concept of resonance based on direct observation of physical phenomena, the more advanced examples are little more than pure abstraction.

When a concept such as the general concept of resonance is introduced to facilitate the acquisition of future related concepts such as resonating air columns, the general concept is termed an advance organizer as it serves to establish an organizational substrate to which new information can be anchored.

Other ways in which advance organizers, or what Novak (1976) calls cognitive bridges, are provided is through introductions to books, chapters, articles, etc.. Introductions are frequently designed to provide an overview or ideational scaffolding to which subsequent ideas can be related. In this sense they serve an organizing role for that which follows.

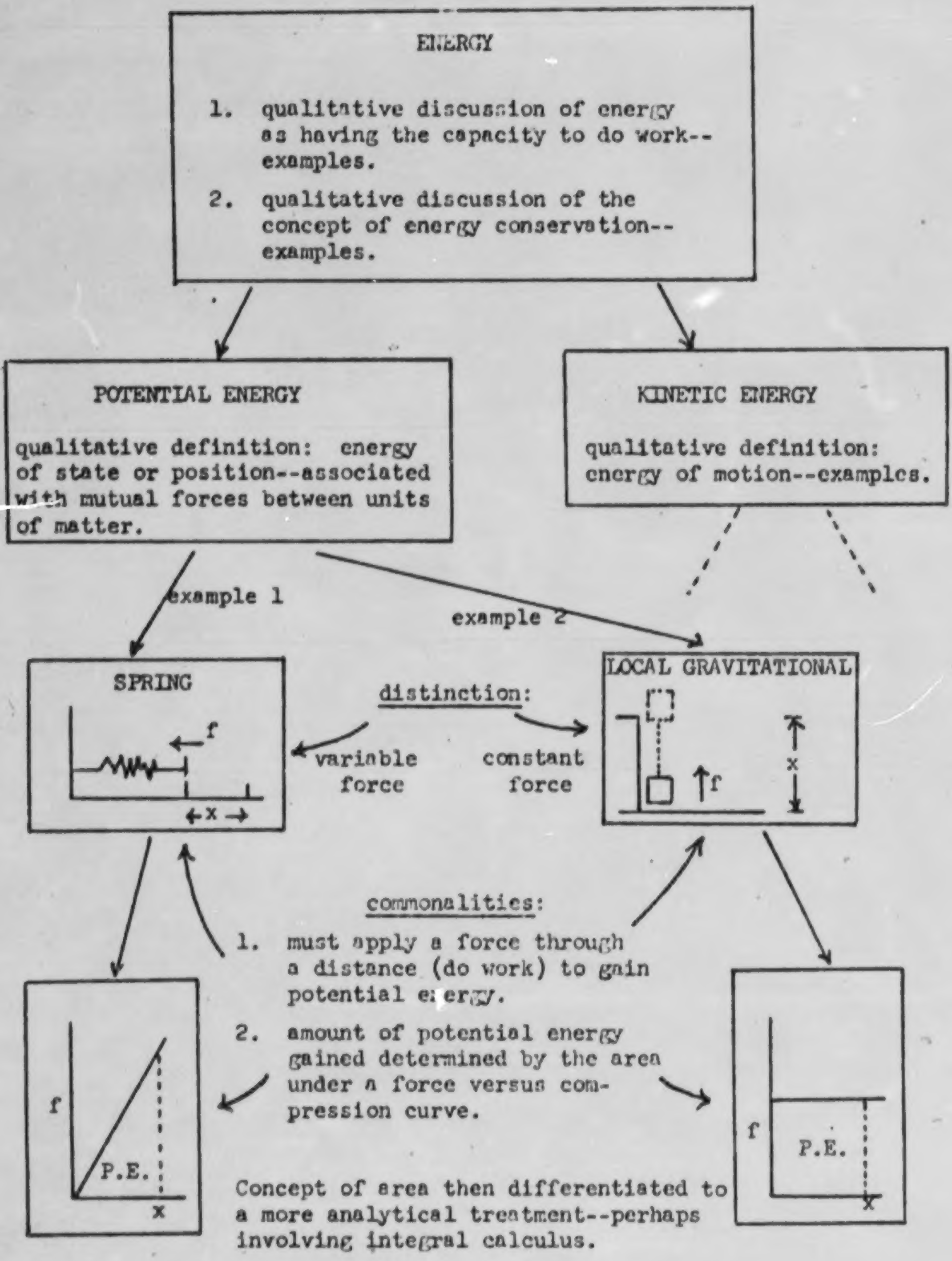
With respect to instructional strategies, these principles suggest that we devote more time to relating the structure of our disciplines to our students. For reading material, this can be accomplished through carefully prepared introductions and summaries (for integrative reconciliation). We should also make strong recommendations to our students to skim reading material before reading it more carefully and to summarize frequently what they have read.

D. An Example from Science (Energy)

Consider that our intentions are to teach the principle of conservation of energy. One might first consider the learner's thought impressions likely to be conjured up by the abstract symbol "energy." High school or college students would certainly have at least a few vague impressions of the meaning of the term; it is generally a simple matter to tie these impressions to a qualitative concept of work. They would also find it reasonable to assume that it is conserved--numerous examples citing common experiences could be illustrated to make this more convincing. The formation of these general, often qualitative, subsuming concepts provides the learner with a superordinate ideational network to which subordinate concepts can be subsequently related (See Fig. 1). Further discussion concerning the specific forms that energy can take would then have meaning by virtue of their associations with the general concepts of work and conservation. Each form, such as potential or kinetic energy, can then be subsequently differentiated to include the previously developed concepts of force, displacement, velocity, etc. while elaborating further the concept of work to develop a more quantitative formulation.

During the process, comparisons between the different types of energy can be made (e.g., the similarities and differences between spring and gravitational potential energy) to provide for integrative reconciliation.

At this point, the decision to differentiate further the potential energy concept would depend on the objectives of the course and/or the objectives of the learner. In a junior high school physical science course or in a descriptive physics course for liberal arts students in college, the choice might be to terminate the differentiation of the potential energy concept


ENERGY
POTENTIAL ENERGY
KINETIC ENERGY
example 1
example 2
SPRING
f
x
distinction:
variable force
constant force
LOCAL GRAVITATIONAL
f
x
commonalities:
f
P.E.
x
f
P.E.
x

1. qualitative discussion of energy as having the capacity to do work--examples.
2. qualitative discussion of the concept of energy conservation--examples.

qualitative definition: energy of state or position--associated with mutual forces between units of matter.

qualitative definition: energy of motion--examples.

1. must apply a force through a distance (do work) to gain potential energy.
2. amount of potential energy gained determined by the area under a force versus compression curve.

Concept of area then differentiated to a more analytical treatment--perhaps involving integral calculus.

Concept of kinetic energy differentiated.

Concept of potential energy expanded to cover wider variety of examples; then concept of conservation of energy further elaborated, etc.

Fig. 1. An example of progressive cognitive differentiation.

and proceed to the elaboration of the kinetic energy branch. In a high school or college physics course for science oriented students a further differentiation would certainly be in order, with perhaps an analytical treatment utilizing integral calculus.

It has been the author's experience that progressing in this general-to-specific manner offers a unique and extremely important advantage in providing for individual differences among students in a given class. The initial discussions are generally qualitative, descriptive, intuitive, and at a low level of complexity. Nearly all students experience success during this stage. As the class moves ahead (discounting self-paced formats), some students, for a multitude of reasons, begin to get lost or bored or simply unable to keep pace due to outside committments. The advantage is realized in that the process of differentiation can be terminated or suspended at virtually any level or point, leaving the learner with a coherent and meaningful set of mental constructs which can serve to facilitate the acquisition and understanding of related concepts in the future. The reverse specific-to-general procedure, although occasionally useful and sometimes necessary, often leaves the learner with an array of dangling, unrelated, and seemingly independent concepts which, even if retained, are not likely to facilitate future learning.

Another important advantage to the general-to-specific progression is that it allows for the discussion of higher level (general) concepts, which are often the more interesting and currently relevant, without the fear that the material has been covered too superficially to be of any value to the student.

Many teachers instinctively feel that a specific-to-general progression makes the most sense. This appraisal might be correct if psychological and logical organizations were equivalent. In practice they seldom are equivalent. For example, consider that a certain understanding of C is dependent on the prerequisite understanding or mastery of A and B. Logically it would follow that we should teach A and B, and then combine them to teach C. There are several problems with this. First, learning A and B independent of any associations with other concepts encourages students to adopt a rote learning strategy. Second, although C cannot be understood "completely" before A and B are learned, it can be introduced at its current level of differentiation and shown in a general way how the learning of A and B will expand their understanding of C. Third, if for some reason C is not learned after learning A and B independently (which is all too often the case), A and B disappear quickly due to lack of anchorage with other concepts. Students who find themselves in this situation, begin to view even the potentially meaningful material as rote in character and experience great difficulty in assimilating the new information. When this happens, mass confusion sets in and students panic with rote memorization, often in the hope that a few glib responses at test time will be interpreted as a reflection of fundamental understanding - when they are successful, they are beating us at our own game!

V. Relationship of General-to-Specific Learning Theory to Other Theories and Practices.

A. Piaget's Developmental Theory

The progression of psychological development from pre-operational to concrete operational, and finally to formational operational thinking is consistent with the general-to-specific model. An individual's ability to progress through these three stages in any content area is closely related to their conceptual development the breadth and depth to which concepts are understood in that area.

B. Inquiry or Discovery Learning

Many view Ausubelian learning theory as antithetical to the aim of inquiry or discovery learning. Although the theory stresses the importance of reception learning, it in no way precludes inquiry or discovery experiences and activities.

The important point, and one that has been expressed by Shulman (1977) and others, is that inquiry and "discovery" exercises and experiments must be preceded and followed by a great deal of teacher directed discussion, consolidation, elaboration, etc. if these experiences are to be meaningful to students. They should not be expected to autonomously discover the physical laws and principles or invent the theories and models which it took the best minds in the human race several centuries to formulate.

A well differentiated conceptual network possessed by an individual, having the power to deal effectively with our ever increasingly complex world, does not come about through autonomous discovery.

VI. Summary

This paper has attempted to provide educators with a brief introduction to the principal components of a comprehensive learning theory based on a general-to-specific, hierarchical view of concept formation. Deliberate attempts to organize instructional strategies along these same lines by focusing on concept learning and the principles of cognitive differentiation and integrative reconciliation, should prove to have a significant impact on advancing the intellectual development of our students.

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TOWARD MORE MEANINGFUL LEARNING IN SCIENCE EDUCATION

Presented by Dr. Carl Naegele

Rapporteur's Report

by Dr. Pinchas Tamir

The group appreciated the major thrust of the paper, namely; the plea for more meaningful learning in science education. The importance of the plea has been found to be especially relevant regarding the erroneous interpretation often given by teachers and even teacher education to the teaching of science as inquiry by inquiry. Many tend to view inquiry as manipulation of materials, busy engagement in observations and experiments with total negligence of the requisite complementary approach of understanding, conceptualization, and consolidation.

The participants raised the question whether or not Ausubel's theory really advocates the sequence from general to specific under all circumstances and whether or not this sequence is always to be recommended. The consensus appears to be that whenever the task at hand is the transmission of organized bodies of knowledge, concepts, theories, and the like, the "general to specific" sequence appears to be the one to recommend. However, such a recommendation should in no way negate the value and importance of inquiry and discovery experiences, provided their meaningfulness is insured. As an example the three related activities provided by SCIS, namely; exploration, invention, and discovery have been brought as an example of how the benefits of inquiry, self-learning, and provision for problem solving can be synthesized to a meaningful learning of concepts.

The need to train teachers in the acquisition of an appropriate balance between inquiry and meaningful reception learning, as well as in ways and means to make inquiry learning experiences meaningful has been especially highlighted.

Some questions for further research have been suggested:

1) What is the best sequence of instruction with different objectives in mind (e.g., skills vs. information)?

2) How do you find out "what the learner already knows" in order to apply adequate cognitive bridges?

3) How do you blend inquiry teaching with Ausubel's subsumption theory when dealing with specific instructional tasks?

SCIENCE EDUCATION RESEARCH FOR THE NEXT DECADE

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and
Dr. Glenn D. Berkheimer

Since its inception, a major goal of the Science and Mathematics Teaching Center has been to encourage and promote better science teaching in Michigan through a variety of services to schools and teachers. This basic goal has remained a cornerstone of Center policy and planning despite evolution of the nature of the services provided. One change began about five years ago when an increased commitment was made to research in science education. This might be viewed as an expression of the Center's commitment to the importance of teaching and learning of science and mathematics in the schools and an extension of the traditional thrust of promoting better teaching.

The research undertakings of the Center are viewed as applied in nature. Thus, each proposed research endeavor should meet the test of having as intended outcomes, specific information or other products with clear applicability to science classroom teaching, curriculum development or teacher education.

Applicability to the classroom, however, is not sufficient to insure that the results of research findings do, in fact, reach those in a position to use them. Research results must be compatible with available mechanisms for dissemination if they are to be useful. Thus, research activity must be coordinated with other Center activities. If no mechanism for using the results exists, then probably one should be created or else the research direction modified. For example, information of relevance in development of curricula will have little impact if no currculum development is taking place.

A third criteria for the Center's research is generalizability. Although this is usually viewed as depending upon the adequacy of the experimental design and sample selection, it is also closely related to the amount of available knowledge of the phenomenon under study. Thus, research should build on and contribute to existing bodies of theory and empirical findings.

No set of criteria can guarantee success of a research effect in contributing to the improvement of teaching. The elements of inspiration, perspiration, and a certain amount of luck are also needed. However, the criteria of applicability of intended outcomes, compatibility with mechanisms for use or dissemination, and generalizability should enhance the probability that our research will contribute to the basic mission of the Center, promoting better science and mathematics teaching.

ORIENTATION

The proposed research directions are an outgrowth of the research conducted in the Center over the past four years, the Center's development and implementation work with elementary science curricula, and the recent work of the Institute for Research in Teaching.

The orientation of the research program can be described in terms of three major aspects: the subject matter, the learner, and the teacher.

Subject Matter

Subject matter knowledge is viewed as organized sets of 1) concepts and related information, and 2) strategies and procedures which are both products of and tools for scientific activity (Smith, 1976). Much of this subject matter is represented in sources such as textbooks and other scientific literature. Other aspects, however, are implicit in the expertise of the scientist and must be gleaned from careful analysis of what scientists do and how they do it. Obviously, for any given course or program, only a portion of subject matter can be taught. Furthermore, as Bruner (1966) pointed out, optimal organizations of subject matter for learning may differ from those used by scientists. Thus, the subject matter for a given course must be selected and organized for instruction. Although this selection depends on the educational purposes to be served, the available alternatives are derived from the concepts, strategies and information from the scientific knowledge base.

It should be emphasized that subject matter is viewed as having both "content" and "process" aspects. However, these are intimately interrelated in ways that make it impossible to completely separate them, even in analysis. Although labels such as hypotheses formation and interpretation of data may be useful in distinguishing broad categories of scientific processes, the learnable, usable elements of procedural knowledge within these categories derive their form and meaning only in relation to specific kinds of conceptual knowledge. Furthermore, the usefulness of process elements such as strategies and procedures is limited by the individual's repertoire of conceptual knowledge on which they can operate.

The Learner

At any point in time the learner posses a repertoire of concepts, strategies, skills, and specific information. This repertoire determines what he can do and the new information with which he can deal, as well as how he can deal with it. As indicated by the work of Piaget, there are developmental constraints on the kinds of operations a child can perform at any given stage. But, within those constraints, there is wide latitude for a variety of science learning. Even at the concrete operational stage, the child possesses very powerful logical structures for learning and using scientific concepts to understand and explore his environment. The specific concepts and strategies the learner has previously acquired are important determinants of his learning of new subject matter.

In the teaching of science and mathematics the Piagetian stages provide some general information about general areas of content and skills, but this information is not specific enough to aid in many instructional decisions. We need to research in great detail the prerequisite concepts and skills students need to learn specific content. We need to research the strategies students use in learning specific content as well as the instructional strategies successful teachers use in teaching specific content.

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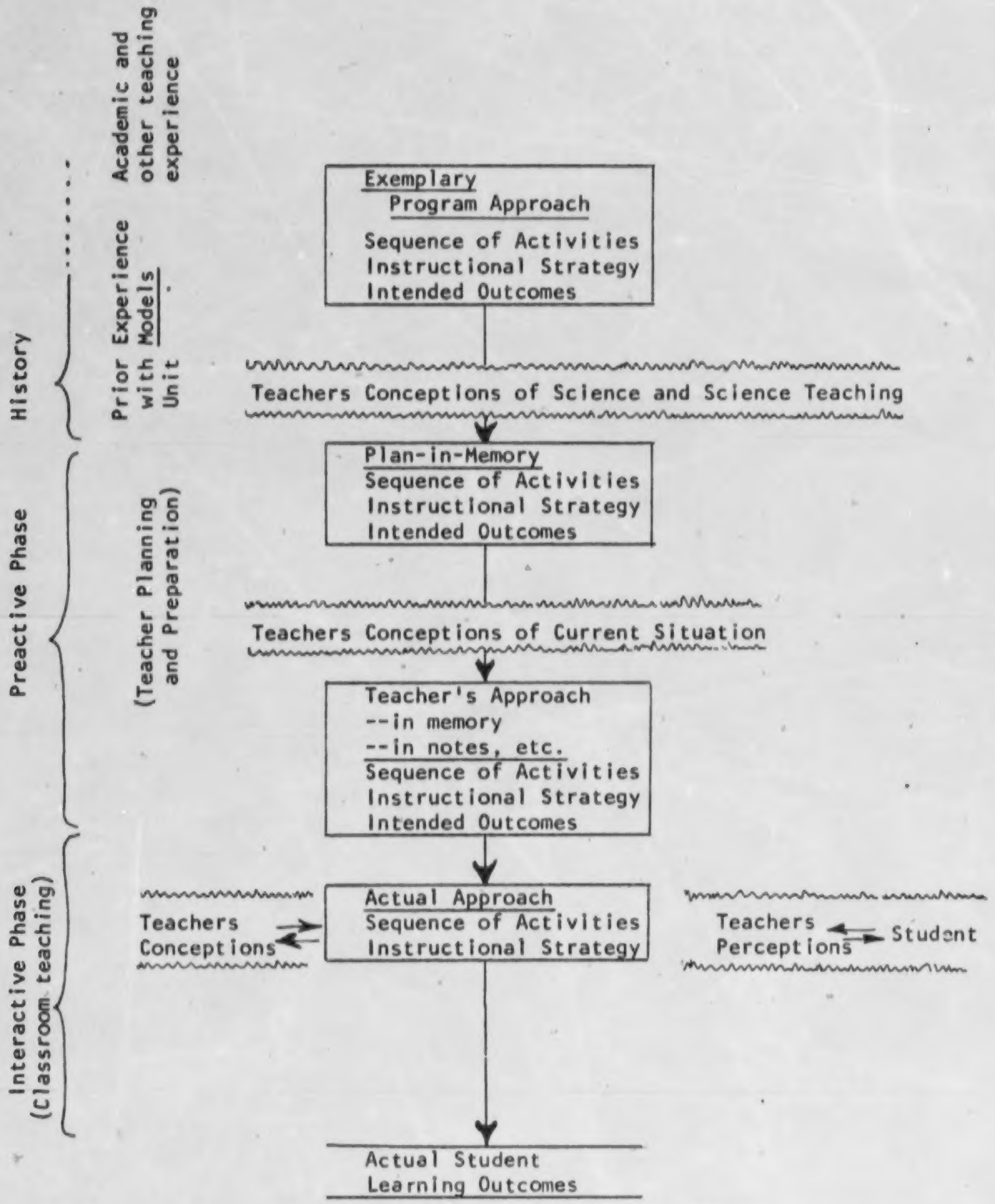
The Teacher

The view of the teacher underlying the proposed research direction differs from that used in most previous research in two fundamental aspects. First, most of the research which has examined classroom teaching has focused almost exclusively on observed classroom teaching behaviors. Most of the attempts to relate teaching to actual outcomes have examined the relationship between these specific teacher behaviors and standardized achievement results. In contrast, the present approach views the teacher as a goal-oriented information processor and decision maker whose goals and plans are major determinants of classroom behavior and ultimately of the resultant learning.

Secondly, most research has examined teaching as a generic activity ignoring the subject matter content and instructional program altogether or has treated them as two of many variables that may modify relatively stable teaching patterns. The present approach, in contrast, assumes that the subject matter and the instructional program impose a relatively large degree of structure on the teacher's thought and classroom behavior. Other variables are viewed as influencing how the teacher acts within and modifies this structure.

These two aspects of our view of the teacher are reflected in the model presented in Figure 1. This model grew out of a current Science and Mathematics Teaching Center research project which is examining teacher instructional goals and strategies using a simulated teacher planning situation.

The view of the teacher as clinician-- goal-oriented information processor and decision maker-- is the cornerstone of the research program of the Institute for Research on Teaching established at Michigan State University by the National Institute for Education (Shulman, 1975). This program has an interdisciplinary orientation and is adapting methods previously used in the study of clinical judgment and decision making in medicine and other areas (Shulman and Elstein, 1975). Reviews of the small but growing number of applications to the study of teaching


History
Prior Experience with Models Unit
Academic and other teaching experience
Exemplary Program Approach
Sequence of Activities
Instructional Strategy
Intended Outcomes
Teachers Conceptions of Science and Science Teaching
Preactive Phase
(Teacher Planning and Preparation)
Plan-in-Memory
Sequence of Activities
Instructional Strategy
Intended Outcomes
Teachers Conceptions of Current Situation
Teacher's Approach
--in memory
--in notes, etc.
Sequence of Activities
Instructional Strategy
Intended Outcomes
Interactive Phase
(Classroom teaching)
Teachers Conceptions
Actual Approach
Sequence of Activities
Instructional Strategy
Teachers Perceptions
Student
Actual Student Learning Outcomes

Model of the Teacher as Mediator of the Exemplary Program Approach - Figure 1.

have been prepared by Morine (1976) and Yinger (1976). These methods include the use of naturalistic observations or realistic clinical task simulations combined with "thinking aloud" methods, and recall of thought and feelings using video recording of the clinical activity as a stimulus. These studies usually rely on several data collection methods to obtain a "thick" description of the activity of each clinician.

GOALS

The purpose of the Science and Mathematics Teaching Center research program is to promote better science and mathematics teaching by producing information and other products which meet the criteria of applicability to ongoing science education activities, compatibility with the Center's available or planned mechanisms for implementation and dissemination, and generalizability to some reasonably well defined set of situations. More specifically, the research will address the following goals:

1. To clarify teacher intentions and objectives of instruction in science and mathematics. This is not simply a matter of identifying specific learning outcomes, but also includes addressing the fundamental question of how to represent them more effectively.
2. To identify classroom practices and activities that can improve the effectiveness of instruction in science and mathematics.
3. To identify in-service and pre-service activities and procedures through which the more effective teaching activities can be encouraged. An important aspect of this goal is to develop a medium of communication between the researcher and the practitioner. A common set of constructs needs to be developed that practitioners and researchers can use, at least so that there is enough overlap for the practitioner to communicate problems that he sees to the researcher and likewise for the results of the research to be communicated to the teacher or curriculum developer in a form that can be used.

PLAN OF ATTACK

The plan of attack is summarized in terms of the series of different kinds of research studies listed below. This sequence is only loosely chronological. More than one study of each kind may be needed for a given topic and the entire pattern may be repeated when investigation of a new topic is undertaken.

1. Analyze subject matter to select a small number of target learning "topics" and identify important learning outcomes for them.
2. Examine instructional approaches to these topics used by "successful" teachers.
3. Carry out baseline studies of pupils which includes the development of procedures for mapping out learners mastery/understanding/competence for the target "topic".
4. Experimentally manipulate instructional approaches employed for the "topics".
5. Experimentally manipulate in-service/pre-service education to influence instructional approaches in specified ways.

The plan of attack is described step by step, laying out in more detail the questions to be asked and the approaches that might be used to answer them.

Subject Matter Analyses

The first area is the analysis of subject matter and involves several tasks.

The first task is to identify or develop constructs and methods that can be used in analyzing a broad range of content to produce good, thorough descriptions of subject matter in the different topical areas. These analyses should be published and made available for purposes of guiding research and instructional development. There are few existing analyses of this type.

The fundamental question faced by this type of research is what does it mean to be knowledgeable, competent, or skilled with respect to a given area? If we look at persons who are knowledgeable, or are skilled, what is it that they know? What can they do? What do they do with that knowledge? What is expert performance like? And how do they do it? What strategies, what approaches do they use for accomplishing the tasks that they address? The people about whom we are interested in answering those questions are:

1. scientists or mathematicians, who represent the respective fields of study,
2. teachers who are relatively expert, and who are tuned in to instruction or who have a pedagogically appropriate structuring of that knowledge,
3. successful students who, by their ways of performing, may be more useful in determining specific instructional goals for a set of new learners than either the teachers or the expert in the field, and
4. those who apply knowledge very successfully. By those who apply knowledge we do not mean the mathematicians, but the clerk who uses computational arithmetic, or accountants, who have skills in manipulating numbers. Other examples may include top rated nurses who handle computations going from grams, drams, and grains, and other units that they have to convert in order to figure out medications.

To study what it means to be knowledgeable, there are two types of analysis needed. One is logical or rational analysis by those who are competent in the subject matter, drawing on the basic documentation of a discipline. The second type is the empirical approach where you bring experts into a situation, have them solve problems, and try to infer what it is that they know that enables them to solve the problem. The necessity of the second step becomes clearer when we look at the research on chess playing or medical diagnosis. People are notoriously bad at telling what they do and yet we have some rather sound research which elucidates important aspects of how particular expertise may be represented.

For example, in chess it has been determined that the grand master does not have a lot of tricky strategies that the master or lower level person does not have, but rather has readily available a great deal more information. The information that the grand master uses is not the positions of individual pieces or individual moves, but rather whole patterns, and he can recognize and construct a great variety of those patterns. It is primarily differences at this level rather than strategic differences that distinguish between categories of competence in chess.

Both logical and empirical analyses are necessary. The initial efforts will probably be more the logical and rational analysis. The details of the empirical approach are similar to some of the methods that are described below for examining teachers' knowledge.

The second task is the selection and analyses of the target learning topics. An example of a target topic is the carrying algorithm for addition. Another is the small particle model of matter that Glenn Berkheimer is currently working on for sixth grade students. Judy Dennison has been looking at childrens' determination of correlational rules, that is, relationships between variables. She has selected variables from three different topics to study for her dissertation.

The criteria for the selection of the initial topics are:

1. The topics should be important, and by that I mean non-trivial with respect to the subject matter area.
2. The topics should be relevant. It should be something that the learner can relate to in some way. They should be interesting or applicable to current problems that the learners are interested in.
3. The topics should be representative. That is, the topic should not be so unique that we never expect to find another example of anything like it.

Some topics that we identify should be theoretically related and provide, therefore, a basis for hypotheses testing. Two areas illustrate this point. One is the transfer of learning by the student. Does the student better understand the second topic, having learned the first one, without having instruction on the second one? Or does he learn the second topic more readily and more thoroughly having had the first topic. From a second standpoint, can we generalize about the instructional approach that works with a given topic? If we design an instructional approach that works with the first topic, does that same approach work with the second one? We are not assuming the validity of these relationships, rather we are hypothesizing and then testing them.

Analysis of the Teaching of Successful Teachers

The second kind of research is the analysis of how successful teachers address the target topics that we identify. The model in Figure 1 illustrates our view of this research problem. We are primarily interested in two questions. What is the teacher's conception of what they are teaching? That is, how does the teacher represent for himself what the student is supposed to be learning? What instructional strategy does the teacher use in addressing the topic and what factors influence the teacher to modify an instructional strategy during the course of instruction or in planning instruction? The factors that affect the strategy may be cognitive or they might be entirely unrelated to cognitive factors. There may be moves to maintain social control or preserve a self image. If three or four students in the back of the room start rustling around and jumping up and down, does the teacher suddenly change strategy? Another related question is, in what terms does the teacher think about the instructional approach?

Information about the teachers' conceptions should help us to understand classroom phenomena and, therefore, to provide more relevant input. In addition, it should help us to communicate more effectively with teachers. A series of different techniques can be used to address these questions. One is to conduct a series of indepth interviews with teachers who are highly regarded for their teaching of a topic. During the interview one would try to probe what they think the key learnings are and how they think they go about teaching them. Although this method has some obvious weaknesses, it is efficient and fairly inexpensive. What teachers say can be quite different from what they actually do. A second technique is to observe how the teacher addresses certain topics in the classroom. Jan Shroyer used this method in her dissertation research under the auspices of the Institute for Research in Teaching. She did case studies of three elementary school teachers' teaching selected mathematical topics. In addition to naturalistic observations, she videotaped the instruction and then used the tape to stimulate the teachers' recall of what they did, what they were thinking when events happened, and what they were attending to during critical moments of the lesson. The intent was to get a clear understanding of the teachers' view of and rationale for what was happening. By looking at the same teacher across several different topics, one can get some notion of whether the teacher thinks in the same terms on the different topics or whether the topics have anything in common in terms of instructional approach.

The third method for examining how teachers address the target topics is using a simulated environment where there is available a range of materials and information that teachers could draw on as the address the task of planning instruction for a topic. We are currently completing a project to develop and apply a simulation technique to examine teacher's intentions for teaching the SCIS unit, Models: Electric and Magnetic Interactions. Four experienced sixth grade SCIS teachers were brought to a simulated planning environment and asked to plan for teaching Part Four ("An Electricity Model") of the Models unit and a hypothetical new part (A Small Particle Model of Matter) for which they were provided an unorganized set of instructional activities. Each teacher's planning activity was video tape recorded. This recording was then reviewed to stimulate the teacher's recall of thoughts, feelings and actions which occured during the planning session. The stimulated recall sessions were audio tape recorded. The set of materials and procedures developed to obtain the planning and recall protocols are referred to as the Science Teacher Planning Simulation System.

The project also provided information about important differences among teacher's intended approaches for teaching the SCIS Models Unit. The results suggested that a 'plan-in-memory' plays a prominent role in structuring a teacher's current intended approach. These results and the model (see Figure 1) devised to reflect them raise a number of promising questions for further research. What factors have been most influential in shaping the teacher's plan-in-memory? What aspects of the current situation influence the teachers to modify the plan-in-memory? How similar is the teacher's actual approach to the intended approach? What factors influence the teachers to modify the intended plan during interactive teaching? How are differences in intended and actual approaches reflected in differences in actual student learning outcomes?

If possession of such plans-in-memory turn out to be typical of most experienced Science teachers and if interactive classroom teaching is as closely related to such plans as the clarity and detail of those we have examined suggest, then the techniques being used in the Science Teacher Planning Simulation System should be useful not only as a research tool, but also as a diagnostic and training device.

Baseline Studies

Baseline studies are studies that examine the students' knowledge state at a given time. The approach that we are currently using is to examine students' ability to perform specified tasks and the strategies they tend to employ. Sometimes it is difficult to interpret the behavior and infer strategies. But we have found a surprising amount of systematic behavior when we have looked creatively enough. The basic assumption is that the learner coming to a new topic is not a blank slate but rather has sophisticated ways of dealing with school learning situations. An understanding of where the student is at the outset can be very useful in planning instruction.

An example is a study of first grade children's strategies for ordering objects on weight and length in which we identified two basic strategies that the children tended to use. On the basis of that study we developed instruction to teach specific strategies to first grade children. We subsequently looked at the effect of the students' developmental level on their ability to learn the alternative strategies for performing that task.

Baseline studies, then, involve the students in tasks relevant to the kinds of learning that are specified for a topic. The key is to specify what you want the student to learn and then devise clever ways of getting at the students' current states of the relevant knowledge. The step of inferring from student behavior the mastery or understanding of this knowledge is, in my view, fundamental.

Experimental Manipulation of Instructional Approaches

The purpose of these studies is to examine the effects of specific variations in the instructional approach for a topic on resulting student learning outcomes.

An instructional approach is a specific set of instructional activities, for which one can form an abstract representation (an instructional strategy) that can be matched to an approach for another topic. Then we can determine if the strategy has similar effects in a new context. (The term 'strategy', implies that there is an abstraction from one situation that can be applied to a new situation). One should not assume that the effects of a strategy will be similar for a new topic but rather hypothesize and test to determine whether they are similar.

To assure that the intended instructional strategies are actually being employed, a very tight control of the instruction is necessary. The experimental manipulation of instructional strategies can take place with teacher collaborators--teachers who are working intimately with the researchers and who know the instructional strategy from close contact with the researchers. Other ways of insuring this control include writing all instructions with the person doing the instruction following the protocol within very tight limits, and the use of video taped instructional input, audio tape, etc. Obviously, some of these controls make the actual teaching less representative of classroom reality than we would like in some ways, but it is a tradeoff. You can gain control at the expense of some realism. On the other hand, if an approach does not work under these somewhat idealized conditions, then one would question the appropriateness of trying to get other teachers to use it in their classrooms where it may be much more difficult to implement.

Important in this kind of study, is the examination of student growth through instruction. In other words, what is happening to the learner, not just on the narrow specific things that he has taught, but also in transfer and problem solving situations. Going back to our hypothesized relationships among the learning topics, we would expect there to be an increment in a person's performance in another related area. We can look for that kind of transfer relationship.

As much as possible, these studies need to examine teacher and student characteristics. Instrumentation on teacher and pupil variables is being developed by the Institute for Research on Teaching and we should borrow what seems most applicable. We assume that the methodology and instrumentation for important teacher or pupil variables will be available. One important example is the coordination of the instructional strategy with the developmental characteristics of the learner. Despite the large number of "developmental" studies in science and mathematics education, few have carefully examined the interaction between developmental level and learning outcomes.

In the course of carrying out experiments of this kind, we will develop a repertoire of instructional activities for the target topics along with assessment instruments and procedures. These products will be available for related studies of the same topics including investigation of teacher strategies and the effects of in-service training. The simulation tasks referred to above may be excellent devices for training on planning instruction, identifying activities that are related to a particular learning topic. The materials that we are identifying or developing for one purpose should have pay offs in a number of other areas of investigation. This is an example of the synergism gained from focusing on target topics from several directions.

Experimental Manipulations of Teacher Training Procedures

The other steps in the plan of attack are designed to generate information or other products of potential value to practitioners. However, to have impact such products need to be integrated into the teaching practices of teachers. Thus, cost-effective teacher education and dissemination techniques must be identified. This last category of research will examine the effectiveness of these mechanisms.

Two levels of research are relevant to dissemination of information or other products to practicing teachers. One level is research on an entire dissemination system such as a network of teacher linking agents located in schools or a series of publications addressing specific needs regularly distributed to science teachers across the state. Research at this level will be conducted in conjunction with the development and tryout of the dissemination model described in the paper by Richard McLeod. The second level of research examines the effectiveness of alternative mechanisms for disseminating specific products. This is the level addressed by the category of studies described here.

The dissemination of information or other products to practicing teachers is not viewed as providing input in one direction on a single occasion. Rather, a continuous, two-way flow is intended. This continuous flow is viewed as having potential as a training device to modify the teachers conceptions and thus to facilitate future communication, as well as enhancing their understanding of the "products" being disseminated. Initial efforts need to provide information as to what is being transmitted, a set of possible learning outcomes for an instructional unit for example. Knowledge of teacher's conceptions of such outcomes and teachers explicit suggestions can be used to devise mechanisms for these efforts. But a certain amount of learning must still take place for many teachers to receive the intended message. After receiving a number of similar messages, however, the teacher should be able to comprehend them more completely and with much less effort. They should also be better able to communicate needs for additional information of that type. The planned research should insure that the Center staff learns how to communicate better right along with the teachers.

Studies should examine teachers' immediate comprehension of specific messages, changes in teachers' intended and actual teaching approaches and changes in student learning outcomes.

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SCIENCE EDUCATION RESEARCH FOR THE NEXT DECADE

Presented by Dr. Edward L. Smith
and Dr. Glenn D. Berkheimer

Rapporteur's Report

by Dr. Joe L. Byers

I am pleased to be invited to participate in this "birthday celebration". It was exciting and stimulating to join with others in the discussion of the papers presented. In the comments that follow I will discuss a concern I have about the future research plans of the SMTC and support other aspects of these plans.

It is "altogether fitting and proper" that the Science and Math Teaching Center should, on the occasion of its 20th anniversary, take stock of where it has been and where it should go in the future. It is not surprising that several of those addressing the question of the future goals and directions of the SMTC have organized their thoughts around themes such as the teacher, the pupil, the curriculum, and the milieu. These are the four commonplaces of education which must be considered in any thorough analysis of education. The Shulman and Tamir keynote address expressly considered the commonplaces. Smith and Berkheimer also examined them in light of the future of "Science Education Research in the Next Decade."

Shulman and Tamir note the failure to address the future in terms of the changing milieu in which Science and Mathematics education are now living may result in their becoming "poignant footnotes in the history of 20th century education" (Shulman and Tamir, p. 25, 1977). Others (Gallagher, 1977) have also taken note of the significance of the "New Climate" now existing for science and mathematics education.

It was, therefore, somewhat surprising to find that the paper devoted to, "Science Education Research for the Next Decade" did not take cognizance of the importance of the milieu for the planning of research studies. It did examine the remaining three commonplaces in some detail and outline a sensible and productive set of studies for the SMTC. Careful examination of the paper and its proposed studies reveals that there are certain lacunae in the plan. It is suggested that these would not have occurred had the authors expressly considered the role of the milieu in their analysis.

Gallagher noted that part of the "new climate" was the misunderstanding of science and mathematics education by parents, teachers and the community in general. The reason for this may well be that educators failed to carefully examine this important aspect of the milieu when devising new curricula. The plethora of curricula which now exists were developed during the last two decades primarily by scholars with aid from teachers and professional educators. It was often the scientists and mathematicians who decided what knowledge in their respective fields was of greatest value. Little was done to help parents (or teachers for that matter) to understand why the "new __________ (fill in your own topic)" was what should be taught to children. Today, laymen will extol the virtue of scientific and mathematical literacy, as do many scholars, but neither understands what the other means by the terms. Unless carefully planned and executed studies are done which reveal the hidden assumptions and meanings of such phrases as scientific literacy, science education will surely suffer.

The age of educational accountability is upon us, and nothing we can do (or should do) will prevent its growth. The problem is not to stop state and local education agencies from inaugurating accountability programs but to exercise a significant impact on their nature. The SMTC is uniquely well situated, through a well-planned series of studies, to influence development by the Michigan Department of Education of accountability programs. Policy capturing studies directed to illuminate the values of various outcomes as perceived by teachers, parents, school boards, and state functionaries might do a great deal to clarify what should be the goals of State assessment of Science and Math. Further, the knowledge of differences in the perceived values of various outcomes of teaching by different constituencies in itself facilitate the negotiations of the differences resulting in more widely accepted accountability programs.

Another, and rather distinct aspect of the milieu which has been slighted relates to the impact of curricular materials on teaching. Smith and Berkheimer (1977) do propose a variety of studies which could be said to touch upon the problem I have in mind here, but none, I think, directly addresses it. Some of the research efforts of the SMTC in the recent past have been rather highly focused on one or two specific curricular programs, (e.g., SCIS). Future plans must look at the full range of programs as they are utilized in schools. How do teachers pick and choose amongst the available programs and materials? Do they combine them? If so, on what basis and to what effect? These questions really follow up on the comments of Shulman and Tamir. The teacher planning study outlined by Smith and Berkheimer is consistent with this notion if it could consider teachers planning outside of a single curricular program.

The proposed baseline studies of student understanding and competency in scientific matters is of great importance. Such studies, if well done and exhaustive of a broad range of valued outcomes, would go a long way toward reducing the ambiguity surrounding the evaluation of science and mathematics teaching. Such studies, I presume, would generally follow the method of a clinical interview. If done in combination with traditional achievement tests, they would help us understand why such measurement methods are believed to be not fully satisfactory as a means for evaluating what children have learned from their studies of science and mathematics.

As I review these notes and the paper to which they are addressed, I am more aware of how little they differ except in emphasis. The criticisms I have made do not, it seems to me, require a reversal of any proposed direction for the future research activities of the SMTC, but rather a slight broadening of the focus to include parties not in science and math education, but highly interested in it.

USING CALCULATORS IN MATHEMATICS CLASSROOMS

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USING CALCULATORS IN MATHEMATICS CLASSROOMS

Dr. Lauren G. Woodby

The idea of using hand-held calculators in school classrooms has suddenly become a dominant issue. The flood of articles in newspspers and magazines of all kinds indicates the intensity of this issue. The question most often discussed is "Should calculators be used in school mathematics?", but this question (however intense the arguments pro and con) will disappear. School use of these amazing devices is inevitable. We simply will have to learn to live with them.

The question really is not "Should calculators be used in school mathematics?", but rather, "How should the calculators be used in school mathematics?" This question merits consideration at all levels, but in this paper, consideration is restricted for the elementary school, principally in grades K-6.

First of all, hand-held calculators already exist in great quantity. Although estimates vary, there is, roughly, one calculator for about every three living persons in the United States. This proliferation will likely continue, because of the low cost. Whether or not calculators are allowed in classrooms, most children already have access to them. In short, calculators are here now and we cannot disregard them.

Another fact to consider is the tremendous capability of these tiny instruments for processing numbers. The capability of a basic four function calculator is much greater than the complicated and expensive mechanical digital calculators of only two decades ago. When memory, square root, and other functions are added the capability is increased. "Slide rule" calculators for secondary school and college mathematics have made slide rules obsolete as calculating devices, and the cost of these calculators is of the order of the cost of a textbook.

One of the most revealing studies on the use of calculators in school mathematics is the NSF supported project directed by Marilyn Suydam.[1] Data for the study were gathered during May, June, July 1975. The purpose of the project was to study the range of beliefs and reactions about calculators, to list the reasons why educators and others believed that the calculator should be used in schools or why the calculator should be banned in schools, and to analyze the arguments found.

The most frequently cited reasons for using calculators in the schools were:

(1) They aid in computation. They are practical, convenient, and efficient. They remove drudgery and save time on tedious calculation. They are less frustrating, especially for low achievers. They encourage speed and accuracy.

(2) They facilitate understanding and concept development.

(3) They lessen the need for memorization, especially as they reinforce basic facts and concepts with immediate feedback. They encourage estimation, approximation, and verification.

(4) They help in problem solving. Problems can be more realistic and the scope of problem solving can be enlarged.

(5) They motivate. They encourage curiosity, positive attitudes, and independence.

(6) They aid in exploring, understanding, and learning algorithmic processes.

(7) They encourage discovery, exploration, and creativity.

(8) They exist. They are here to stay in the "real world", so we cannot ignore them.

The most frequently cited reasons against using calculators in the schools were:

(1) They could be used as substitutes for developing computational skills: students may not be motivated to master basic facts and algorithms.

(2) They are not available to all students. Because they cannot afford a calculator, some students are at a disadvantage.

(3) They may give a false impression of what mathematics is. Mathematics may be equated to computation, performed without thinking. Emphasis is on the product rather than on the process; structure is deemphasized. Mental laziness and too much dependence are encouraged; lack of understanding is promoted. Some students and teachers will misuse them.

(4) They are faddish. There is little planning or research.

(5) They lead to maintenance and security problems.

The section of the report summarizing the recommendation from educators contains such a variety of beliefs and is so diverse that it is difficult to obtain consensus. What is clear is the uncertainty that exists among educators. There was an element of caution e.g. "Use in early grades with care if at all" and "Do not ignore computational skills". At the other extreme there was evidence of a desire for major curriculum change e.g. "Change teaching emphasis to concept development, algorithmic processes, and interdisciplinary applications". One interesting recommendation that makes sense is that every teacher should learn to use calculators just in order to find meaningful ways to use them.

Any review of literature concerned with the use of calculators in the classroom should include some of the work of David Moursand,[2] University of Oregon. Much of his material is published by the Oregon Council for Computer Education, 4015 S.W. Canyon Road, Portland, Oregon 97221. He believes that the purpose of calculation is insight not numbers, and suggests the following three basic goals for mathematics education:

1. Probably the most important goal is to learn to do mental arithmetic and to make mental approximations.

2. Each student should learn to understand, represent, and successfully deal with a wide variety of arithmetic and geometric concepts in problem situations.
3. Each student should develop abilities and attitudes which are conducive to future learning and use of mathematics.

Although he proposes a decrease in emphasis upon pencil and paper arithmetic and an increase in mental arithmetic, with calculators available to all, he thinks this change will occur slowly because parents and school boards view basics as pencil and paper computation. Use of the calculator is considered "cheating".

In his book (not yet published), Moursand[3] examines four categories of calculation:

1. Exact mental calculation (for example, use of memorized number facts).
2. Approximate mental calculation (for example, making mental estimates).
3. Pencil and paper assisted calculation.
4. Calculation using other aids such as math tables, calculators, and computers.

The big problem facing mathematics educators is to determine an appropriate balance among these four categories. For years the emphasis has been on the first and third, the second has been slighted and the fourth has been almost completely ignored. General acceptance and use of calculators would have four profound implications:

1. Goals for mathematics education would need to be rewritten.
2. All mathematics texts, course outlines, and curriculum guides would need to be rewritten.
3. All standardized mathematics examinations would need to be rewritten or renormed.
4. Almost all elementary school teachers would require substantial in-service training.

Another source of information about the use of calculators in the elementary school was the curriculum development project at the University of Chicago, under the direction of Max Bell.[4] In this relatively small project, supported by the National Science Foundation during 1974-75, Max Bell and five colleagues studied the elementary school mathematics experience in a few schools near the University of Chicago to find out first hand "what is really going on" and explored some ways to improve that experience. One aspect of the project was the use of calculators by the students and the teachers. The experimental tryouts with calculators were quite informal and occurred mainly in grades 1 to 6. Some observations and impressions reported by Bell are:

1. Children of all ages and of all ability levels responded immediately and enthusiastically to the opportunity to work with calculators.
2. Generally, it is unnecessary to give instruction for using calculators. Children figure out how to use them.
3. At first, children do "everything in sight" on the calculator but quickly settle down into selective use.
4. There was apprehension from most teachers and downright resistance from others about using calculators. There was a general feeling that using a calculator is cheating and students computation skills would decline.
5. There was uneasiness about security of the calculators. Teachers feared they would be stolen.
6. One seemingly trivial but real difficulty was the replacement of worn out batteries.
7. Most of the 39 teachers believed that calculators might be appropriate for children who have already learned computation. However, in one first grade and in a third grade remedial summer school, it was observed that calculators had high potential for helping children in explorations about numbers.

8. Reversal errors (i.e. reading 87 for 78) may be caused by calculators that feed in from the right, as most do. A few machines (e.g. Hewlett-Packard and Novus) feed in from the left.

9. There appear to be rich pedagogical sequences possible from children's questions about $\sqrt{x}$, 10^x, etc.

A useful outcome of the project, was the clearer picture of current elementary school mathematics experience that Max Bell reported. (As an aside, this outcome is exactly in accord with one of the recommendations in the NACOME Report - to obtain more first hand information about what is really going on in mathematics classrooms). In his report, Bell states "our most discouraging finding is the gulf between prevailing school practice and a widespread consensus outside of schools that the early school mathematics experience should be solidly anchored in activities, direct experience, playful manipulations, and so on, with mathematical ideas built into these experiences . . . yet most classrooms have none of it at all." He found that the curriculum in the schools studied contained almost no work in estimation or approximation, only rudimentary applications, and little in the way of handling data.

Following his analysis of the present elementary school situation, Bell concludes that it would be disruptive to put calculators into this curriculum. Instead, he suggests that it is necessary to devise alternative curricula with calculators in mind. What the calculator does well is not reflected in the present curriculum. For example, the calculator allows for the handling of more complicated data. It makes trial and error methods feasible in many contexts. Exploiting the calculator requires estimation skills not currently taught in the elementary school, but needed in real life situations.

The November 1976 issue of The Arithmetic Teacher was a special issue devoted completely to calculators. The article by Shumway "Hand Calculators: Where do you stand?" summarizes most of the arguments for and against the use of hand calculators. This special issue reflects a range of concerns by a variety of people and also indicates the current importance of the topic.

The papers resulting from a recent seminar in England on the use of calculators indicate that the British are more concerned with the question of how to use calculators rather than whether to use them. The cover sheet for this collection of papers (not yet published) is very simple: CALCULATORS HAVE COME. The paper by F.R. Watson, "Using a Calculator to Investigate Patterns", closely parallels some of the work of George Immerzeel, University of Northern Iowa. For example, pattern

1

1 + 3

1 + 3 + 5

1 + 3 + 5 + 7

. . . .

can be investigated with or without the calculator. The advantage of using the calculator is that it removes the burden of arithmetic, leaving the pupil more free to think about the pattern.

Considerable attention in this seminar was given to the question of using calculators on examinations. Many teachers in Britain are opposed to further erosion of simple arithmetic skills and favor banning calculators in examinations specifically designed to test "numeracy" as one of their objectives. However, the direction of change is to allow the use of calculators in all other examinations, mathematical, and otherwise.

George Immerzeel, University of Northern Iowa has been one of the most prolific developers of materials for classroom use.[5] Moreover his materials are tried out with children in the Malcolm Price Laboratory School before publication. The "77 Ideas for Using Calculators" is one of the best collections available. He has included some excellent examples on problem solving, concentrating on real problems in the real world. Teachers will find these materials ideal for getting acquainted with the calculator. Activities are organized under the categories of counting and numeration skills, computation skills, number concepts, estimation and rounding, common fractions and decimals, calculator games, measurement, and problem-solving.

The National Council of Teachers of Mathematics recognizing the high priority of the topic of hand calculators included an extra, non-thematic chapter in the 1977 yearbook.[6] This chapter begins with a review of the strong statements made about the use of the calculators in the report of the National Advisory Committee on Mathematical Education (NACOME). Other sections in the chapter summarize the questions and discussion concerning calculators from the Euclid Conference, the NSF Study by Suydam, and the June 1976 Conference on the Uses of Hand Held Calculators in School Mathematics. The chapter provides a clear picture of the uncertainties involved and the implications for research and development. Every teacher of mathematics should read this chapter. Two of the summary statements are exactly the notions that motivated this paper. They are:

1. The calculator cannot be ignored: its use in the schools must be carefully explored.
2. The focus of attention must be on how the calculator can best be used to develop and reinforce mathematical skills and ideas.

In June, 1976, the National Science Foundation and the National Institute of Education supported a conference in which a small number of highly qualified people took a hard look to see what course the schools should take concerning the use of calculators. The dominant purpose of the conference was to establish leadership in helping schools adjust to the existence of calculators. The fact that calculators "have the potential for replacing the pencil and paper calculations that have been the major (and often the sole) component of elementary school arithmetic", has made the topic both urgent and controversial.

The conference discussed both short-term and long-term curriculum developments that are needed to accommodate to the use of calculators. The Introduction to the Report[7] gives some tentative guidelines for research and curriculum development. It closes with the statement:

"For millions of people everyday arithmetic will never be the same."

The 22 detailed recommendations in Chapter 2 of this Report are grouped under the following broad areas; development of an information base, development of curriculum materials, research and evaluation considerations, teacher education, and dissemination. One of the recommendations is to establish a central information collection and dissemination center. This has already been done. The Calculator Information Center is located at 1200 Chambers Road, Columbus, Ohio, 43212.

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USING CALCULATORS IN MATHEMATICS CLASSROOMS

Presented by Dr. Lauren Woodby

Rapporteur's Report

by Dr. Ronald Sargent

The issue of hand calculators in the classroom may be paralleling the issue of television in the schools. Educators have had available technology in the form of T.V. for many years, but have failed to develop methods to gain maximum instructional utilization of the technology because of lack of expertise and because of the debate that continues over the value of the instrument as an instructional tool. The debate centers around whether basic skills can be taught through T.V. or whether it is an entertainment medium.

This same situation appears to now be existent for hand calculators. Educators have not developed instructional programs for the calculators and many perceive the calculator as a toy in the hands of students and feel it interferes with, rather than supports, the development of basic math skills.

During the discussion session regarding hand calculators in the classroom, this problem of attitude and acceptance was addressed. The group felt that many teachers feared the use of the calculator and rejected them because they viewed the calculator as a deterrent to mastering the basic skills of mathematics. It was also felt that many teachers viewed the calculator in the hands of children as toys rather than as instructional tools.

To address these problems the group felt that specific goals and objectives should be developed for a hand calculator program consistent and compatible with existing purposes of math education. In this manner, parents and educators could be reassured that the math program would maintain in the same form and with the same standards. Utilizing the goals and objectives, a series of experiences could then be defined that would incorporate the hand calculator into the instructional program as a learning device rather than as an instrument to short-cut the learning of basic skills. Hopefully, the classroom activities would lead to an attitude that perceived the hand calculator as a device that could be utilized to teach math skills rather than as a supportive device. It was suggested that workshops be designed for teachers which would focus on the following specific items:

1) the specific use and operation of hand calculators;
2) specific _instructional_ activities utilizing the hand calculator; and
3) a hand calculator curriculum correlated to the basic math program.

It was also clear that there was a lack of research information regarding the hand calculator as an instructional tool and it was felt that research programs should be established as soon as possible to substantiate and/or support continued efforts to implement hand calculator programs in the schools.

CLOSING ADDRESS:

FUTURE ROLES OF UNIVERSITIES AND PROFESSIONAL ORGANIZATIONS IN IMPROVING SCIENCE AND MATHEMATICS EDUCATION

Robert Silber
Executive Director,
National Science Teacher's Association

CLOSING ADDRESS:

FUTURE ROLES OF UNIVERSITIES AND PROFESSIONAL ORGANIZATIONS IN IMPROVING SCIENCE AND MATHEMATICS EDUCATION

Dr. Robert Silber

This has been a very interesting meeting. It was interesting to have reviewed, the events of the 1950's and 1960's in Education and Science Education. During that period I visited MSU and called a former student of mine who was attending Michigan State University. During dinner with him, I asked, "Jim, how are you doing at Michigan State?" He said, "I am doing fine, I am President of my fraternity, I am President of the Inter Fraternity Council, and I am Past President of my class. But he said I am about to give it all up because I can no longer stand the unfairness of life in fraternities."

Now I would submit to you that this was in the hey-dey of fraternities and this young man was trying to deal with the particular problem of prejudices and fighting against all kinds of opposition. I recount that today because i am reminiscing about the Center and at the same time thinking about that student and how far I believe we have come. I wish this conference and your anniversary came just about a month later because the National Science Teachers' Association has a committee working on a position statement on science education for the next X years. Several approaches have been tried and at least one or two of you have participated. I am going to give you my own thoughts and they may or may not be common with what is in the paper.

I actually want to mention six concerns that I have. Hopefully, they are concerns that you share. The concerns are varied. They seem not to hang together too well as I was reviewing them and thinking about them further, but perhaps they do.

The first concern I would like to label "sensitive signals". The world we live in today is moving so fast, as you all know, that we must be very sensitive to the signals that are being put out to us, we cannot be locked in to paths that we have followed in the past and expect them to lead anywhere that is significant. We must look for signals in every place where we can look and decide which way to go. I might say that one of the premises that has been decided relative to the position statement of NSTA is that it will not be written as a position paper that will stand for ten years, or any number of years. It is going to be a dynamic paper that is continually changing in its outlook relative to where we are going. Because that is the world we live in today

Now, when I say "sensitive signals" I would like for you to think about looking to students at all levels. What are the students saying they need to learn in this world? What are students saying they think is going to happen? If you're university level teachers, you certainly should look to the teachers to see what is happening in the classroom at the elementary, middle, junior high, high school. There are our signals.

I think we find our signals other places. You are surrounded with signals today. I think it is an excellent idea that Jim gathered art that is oriented around science. The signals are coming from artists and from writers and from popular songs and from popular books. We must keep up in those areas to detect the signals: Where are the people hurting?, where should we be going? One of the problems we have to face, and it is very difficult to face, because it is one of the most difficult unknowns is, "What is the world going to be like tomorrow so that the kids can work and find jobs?" What is that work that we have to be ready for?

We have other signals which are very clear. Some we have chosen to ignore. The pipeline is full of kids. We know how many there are in this country and in every county, town, village, and city. They will be shifting around but we know how to make projections and we should know what is going to happen relative to the number of teachers and the numbers of schools needed. There is no excuse for not knowing. A community like mine, Montgomery County, Maryland, supposedly one of the better school systems in the country, did not foresee this. They hired a superintendent to close schools. The enrollments are down, the teachers are leaving, there is no money--one of the richest counties in the country. Now we knew that was coming, why didn't we do something about it?

Colleges and universities are changing and for you people here on the campus, I am telling you nothing new. Colleges and universities are seeking new kinds of students. Where do we get students from different sources? Universities are changing their offerings. Universities have aging faculties and they are slowing down as employers of Ph.D.'s. Many colleges are closing or combining with other colleges and universities are shifting the focus of their research. College students enrolled are involved in retraining, vocational education, continuing education, and education as creative leisure. It is a different kind of a ball game.

The second concern that I have is one that I choose to call, "continuing consumption." Consumption in that sense means to consume education in a continuing way. It is trite to say that we need to keep up with change; it is absolutely obvious. We were trying to deal with that fact this morning and this afternoon. How do you do that? For teachers it means content in science and mathematics, it also means how you teach your subject. One must keep up in those two areas. But in recent years there have been two new areas added and that doesn't ease the burden. One new area is the relationships to the real world. We must look at society's problems in the science classroom, the social science classrooms, and many other classrooms. Whether you are teaching chemistry, biology, earth science, or elementary school science, where the children are or where the children's parents are is the real world and for too many years we have ignored the real world, turned children out and asked why they don't pass chemistry, why they don't understand physics. I submit that there is another area that we haven't attended to very well and it is so important I will mention it here but devote more time to it later. That concern is human relationships. That is the fourth thing that we need to bring to teachers. How are they getting along in their interpersonal relationships with other teachers and supervisors and administrators, but more important, the children in the classroom. Well, what we are trying to do with NSTA, I guess, is to look at this "continuing consumption" and see if this organization and others like ours has anything to say or do. So we have started a continuing education program. It is starting slowly. I think it has been thought through very carefully, but we are limited, as everyone else is with staff and money so we do what we can. Let me just mention a few things that we are trying to do.

It is terribly important for science teachers to know what is happening in industry. Teachers go through college and right into the classroom. Most of their students work in business and industry when they get out and teachers know nothing about it. What a shame! What a waste of knowledge and energies that are available in business and industry. In addition, industry needs to have a better way of portraying their goals. Right now, they have the worst image they have ever had and for business and industry officials that I have talked with they are trying desperately to figure out how they can convince the public that some of what they are doing is okay. Well, NSTA is trying a program for teachers involving a three week workshop with industry. During the first week, teachers learn about the business and industry they are visiting. The second week the teachers end up in a research facility where they see scientific principles that they teach, applied. And the third week they are asked to prepare materials to be used in the classroom based on what they say in this industry. Industry pays these teachers for this experience. Three week workshops were held last summer with four industries. The letters I got were just phenomenal--both from the industries and from the teachers that experienced it. Teachers talked about it as one of the greatest experiences of their lives. One industry in New Jersey was so enthusiastic about a teacher that came to the program last year, they said they must have her back. "She is one of the most fascinating people we have ever met." She impressed everyone she came in contact with, and they are setting up a special program for her to back this summer.

There is another whole untapped resource--research institutes connected with the university. Scientific research institutes where interesting work is going on in special fields. There is a whole host of people that haven't much of a way to share what they are doing with others except in their research journals, and the ones I visited really would like to have teachers. So we set up some courses. Now, I am calling those "unique experiences". The first one we set up was in St. Croix in the Virgin Islands. Fairley-Dickinson University has a research institute in St. Croix in marine ecology. We set up one at the University of Miami, Rosenteil Institute of Oceanography, Skidaway Institute of Oceanography of the University of Georgia, and we are working on one at Colorado State University on the grasslands biome. The teachers that went to these came back tremendously enthused about what they did and what they saw.

You say teachers won't participate, maybe we haven't figured out why they won't participate. I would like to suggest that one of the things we have been trying to figure out, is a way to offer short courses at our conventions. I need universities who will help me put together some courses that are very viable, topics that teachers want to know about.

You might be interested that we also are very much concerned about the fact that research seems to be done in universities but by the time that it ever gets applied, many years have elapsed. MSTA has just received a grant from ERIC in which we are putting together a synthesis of research in science education. Six topics which will be published. These papers are being prepared by leading researchers in the country. We also received a grant from NSF to put those authors in workshops at NSTA conventions, to discuss how research is practically applied in the classrooms.

Teachers desperately need help, citizens desperately need help. A recent survey of people on the street when the surveyor said, "What is the source of electricity that we use in your home?" 90% of the people on the street said it comes out of a plug in a wall. 50% of elementary teachers asked that, said the same thing. Now if you think that is funny, we have a problem. We really have a problem.

The third thing that I think is a concern, I like to call "power playing". In the late 1800'a there was an informal group formed called The Scientific Lazzaroni. The Scientific Lazzaroni was a small group of leading professors from Harvard, MIT, etc., in the Boston area and they decided that they would meet once a month and "eat a ravenously good dinner together." Well, they did that. The word Lazzaroni means "idle beggars", and that's what they wanted to be called--Scientific Lazzaroni. They ate dinner together once a month.

Do you know what happened to that group of idle beggars? They decided that the country at that time was in such bad shape that they might be able to have some influence. Scientists, I am talking about, and they started to see what influence they could have. And, if you read about the Scientific Lazzaroni you will see what influence they had. One of them became Head of the U.S. Naval Observatory, another one became the Head of the Smithsonian Institution. This was in a period of about 3 to 5 years. They thought there should be established a National Academy of Science, they got that through Congress at the last session about 2:00 o'clock in the morning when the

Congressmen were so tired they signed it and the President signed it and the National Academy was established and one of these people headed it up. They headed up six to eight of the most powerful positions in science in the country at that time and they controlled the sciences.

Now, I am not suggesting that that could be done today, I am suggesting that we do need to participate in the political arena if we are going to get some things done in science education. And that means some "power playing". Now, NSTA does not wield much power. We are not allowed to lobby as an organization, although that has been loosened up greatly and we can do much more than we have. But there are ways to reach Congressmen and the important thing is to be there when it counts. We need to be activators, rather than reactors to events. We need to lead instead of waiting to be called.

My fourth concern is science support. Lee Shulman this morning talked about the great relationships developed between scientists and science educators in the curriculum study days. Beautiful. How many teachers I talked to during those days that said, "Couldn't this continue, what a great relationship this has been "

Science recently has taken a terrific beating. The general public is not sure about science and technology. And science research until the last year or two was hit very hard when cut-backs were made. We don't need the curriculum studies now but we need the cooperation with scientists to disseminate the science information that they know. We as science educators, can help with that. They need help to talk about science to the general public and they don't always know how to do that. We need the liaisons again between scientists and science educators to disseminate information. Well, I think it is interesting NSTA has become a member of the Council of

Scientific Society Presidents. This is a representative group of Presidents of most Scientific Societies in the country, NSTA is there. NSTA is the one who proposed and had accepted the establishment of an education committee within CSSP. NSTA also started an informal group, the "Council of Science Teaching Societies (COSTS)." Biology teachers, physics teachers, geology teachers, all come together periodically to talk about the problems that are common and things that we might do together on a cooperative basis. Scientists need science education and we need them.

The fifth thing that I am concerned about (and now I am departing perhaps a little bit from what you might expect me to say) I tend to call "living life". Now you can talk about science education and math education and any kind of education you want, but the important thing that happens is that we have a life to live and there is only one person that can do that. But all of us need help and we are living in days that are terribly trying. Sometimes I talk to people about problems the world is facing that I think are important, such as, energy, population, and pollution. They say "hey, we're just trying to earn a living." "We really can't be bothered with those, I have to feed my family and clothe them and house them and keep a job. I really don't have time to think about whether we are going to have enough energy."

Now, you see that is where we are in the classroom, because the students that you teach have parents that are making those livings, and that's where many of the parents are today. Where unemployment is terribly high, what do you do with that? We not only have the problem of earning an income, to provide for a family, or whatever; we have the society problems and you have the constant problem of interpersonal relationships. Competition, confrontation, controversy; one can see these three in action every day.

In a restaurant, observe the waitresses and their interactions with customers, each other, and with the boss. Go for a ride on an airplane or on the train or go to the store. Everywhere you go there is competition, controversy, and confrontation. And when people get home at night they don't have too much time to think about energy problems. I call this "life stride". We need some kind of stress release from this kind of situation and if you are a good teacher you damn well know that the kids in your classroom are hung up on stresses and you just got to be ready some days to talk about that. The plan you had for that day will have to be shifted to the students' immediate needs.

I am sure all of you have read a very interesting book that I thought was terrific called, Zen and the Art of Motorcycle Maintenance. Robert Pirsig said in one part of that and I quote, "It is not the technology that is scary, it is what it does to the relations between people, like customers and operators that is scary."

The last concern I have is probably farther fetched for some of you and you can't imagine why I would be saying it here. But I believe it almost becomes a summary for me, because I think that is where it all is. I like to talk about problems in science education and I like to talk about other problems that we face in the world but it seems to me like the one problem that we have is right here and if we can figure out what's happening there, a lot of the other problems are solved. So I entitled this section "Liberating Love". You can call it anything you want and I can't define it. Whether you call it humanistic education or it is learning in the affective domain, I have an inherent feeling that we all know what we are talking about. And what we are talking about is how do you as a teacher relate to that student in the classroom.

If you really care about that student then things happen in the classroom. Now, you can be super prepared in content and you can know all the latest methods and if you don't care about what happens to those students nothing happens. Now, you see the tragedy of all of this is that there are two problems with it. One is that you have to be okay yourself, and feel okay about yourself when you walk in that classroom. The other problem is that you need to love those students or care enough about them to say "hey, we're here as a team to do something." To do something today happens to be science, but what we are really talking about is life. Now, the problem for a university is, how do you get a hold on that? I have been to a lot of campuses. I haven't found many that have a course on interpersonal relationships in the training of science teachers. Not only do I not find many courses, I don't find any parts of courses and that disturbs me. Now, part of the problem there, I think, is that we don't have a good framework on which to hang all this. We can't say to a teacher "hey, if you do this and you think this way and go into a classroom everything will work out all right." It doesn't happen that way. We need some kind of model or framework that really works and when some kid comes in and slams a book on the floor you need some way to know what is happening to that kid and his interaction with you.

I thought there was a very interesting piece written by someone I am sure you know, Joe Advestato, from the University of Vermont. He wrote a piece called "Love in Science Teaching". Perhaps you have heard him read it. I will just read a section of it because it sort of says what I am trying to say. "To teach is to love--to love to share, to love to help others grow and stretch and reach and hope. To love is to risk--to risk helping when our students may not wish to be helped, to share with those who may wish to be alone, to risk cultivating growth when a student may be content to stay where he is. To risk getting students to reach for the stars when their eyes see only the ground."

It has been interesting for me to look at science education over a number of years and try to think where things are going. Some people say, "Education is cyclic and all of the things are coming back and back to basics we go." I would submit that one of the reasons we periodically go back to basics is that so many of the things we have held sacred and we hold on to like family, church, and government are shattered, so we have to go back to something that seems to be stable, back to basics. Also, when money runs out, we go back to basics.

In one of Carlos Castenado's books, he wrote about a journey. When asked about this journey, Don Juan says that you never really reach the city, it's the journey that counts.

I want to congratulate you on this beautiful history of the Science and Mathematics Teaching Center, the fine people that have been associated with it, and the great leadership of the University. I thank you for the privilege of being here.